Papers on Education

BY

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PREFACE

The publication, in a collected form, of the papers included in this volume may not be without value at the present critical juncture of educational affairs—when so many serious attempts are being made to bring our school system into harmony with the times and to improve the methods of teaching.

The earlier articles are didactic: in these I have sought to give reasons for the introduction of scientific method into all schools. The later articles are constructive: they contain the suggestions which, from time to time, I have ventured to make for the improvement of the methods of teaching elementary physical science. Whilst the former may be of interest to the general reader, the latter will appeal more to the specialist.

In the last article, in which the question of school workshops for experimental studies is considered, I have urged that the provision made in future should be full but simple. It is very important, on account of the great educational value of such work, that it should be understood that there need be no excessive expenditure for this purpose—indeed that the work is

best done under simple conditions with simple appliances, space and efficient teaching being the chief requisites.

The essays cover a period of about twenty years. They are not arranged in any chronological order. No doubt, they all deal mainly with one topic, so that I may be open to the charge of somewhat unduly repeating my argument: if I venture to put them forward, it is in the hope that such repetition of a plea may add to its cogency and carry conviction—at least of my own belief in its urgency.

The fourteenth article is my maiden essay—in it will be found the germ of all my subsequent work. This essay may be of interest to teachers, if they will compare it with the later articles and mark the gradual development of the method of treatment which is foreshadowed in it, now known as the Heuristic method.

Parenthetically, let me here at once say that I am not responsible for the introduction of this word, still less of the principle included under it. The method, in a sense, is as old as the hills—in fact, it is the method of nature: of the animal creation; of the human infant; and yet, as now practised, it is essentially new in the completeness with which its advocates seek to correlate experimental inquiry with both inductive and deductive inquiry and is, in this respect, a great advance upon the Socratic method. Its use has been advocated over and over again. But it has fallen into disuse, having been almost lost sight of since literary methods have secured the mastery in schools. Desiring

to develop the method and extend its use, I have ventured to lay emphasis on a name for it which is eminently suggestive and descriptive, whilst being an admirable contrast to the antithetic term didactic—however much it may meet with objection from the classical purist.

But in advocating the introduction of *scientific method* into schools, still more in advocating that teachers generally should have mastered the experimental method and be able to assume the attitude of the investigator, I know that I shall command the support of few—simply because, at present, so few can appreciate what is meant by such expressions. And yet it is very necessary that they should be understood by all. It is the office of the teacher to carry his pupils forward; his success depends on the extent to which he displays individuality; and the one all-potent means of developing a constructive and imaginative habit of mind is to engage in inquiry. The teacher who acts merely as the mouthpiece of others is only fit to train parrots; he cannot fail to exercise a narrowing influence on his pupils. Man is by nature a reasoning being and needs to be treated as such; unfortunately, in schools, this fact has been more honoured in the breach than in the observance.

In the course of a century or so, the introduction of the experimental method has led to the most extraordinary advance in knowledge; the infinite beauty of natural objects and phenomena has been disclosed to us; control has been gained over natural forces and

the engineer has acquired dominion in consequence. But, as yet, no organised effort has been made to put our youth in possession of the new knowledge—to enable them to grasp its meaning and importance and to make use of it: forced still to concentrate their attention on pious Æneas and on Cæsar, they hear nothing of the great engineers, of Black, Cavendish, Dalton, Darwin, Faraday, Lavoisier, Liebig and many others, who in modern times have made the world of to-day what it is.

While the classes which formerly stood out as cultured are falling behind, a new intellectual order is arising, comprising the workers in various branches of science and engineers—men of deeds rather than of words, who are all striving to go forward and to give peace to society, true missionaries in the cause of progress. However much their work may be delayed by ignorance, they will eventually conquer, as they have no selfish ends and are bent on bringing mankind into intimate touch with nature.

Hitherto our schools have been too much in the hands of men unpractical by habit and too often unpractical by nature—trained to dogmatic beliefs and therefore without the freedom of mind which is absolutely essential to the teacher. Consequently, education has had little reference to the wants of the world: its tendencies have been illiberal and narrowing; worst of all, a one-sided, selfish devotion to humanistic studies has induced an attitude of blindness, indeed of irreverence, towards natural objects and phenomena.

Until practical men and women are put in charge of our schools, there will be little progress—there are enough cases of success already to prove this to demonstration.

Teachers such as we need will not be forthcoming, however, unless the universities take a far broader view of the situation than they have done heretofore. It will not suffice to supplement the ordinary degree course by a year's study of pedagogics—although such study will have its value. Talking will not make teachers—little more than the mere tricks of the trade will be learnt in the practising school: real teachers will only arise when the training given is such as to develop thought-power and some understanding of the art of experimental inquiry.

In the case of articles previously printed elsewhere, the place of publication is indicated in the table of Contents. I am much indebted for permission to republish the articles to the editors of the publications named—especially to the Council of the British Association; to the Board of Education; to the Editor of the *National Review*, Mr. Maxse; to Mr. Murray, the publisher, and Mr. Laurie Magnus, the Editor, of *National Education;* and to the Council of the Royal Institute of British Architects. I have also to thank Mr. Maurice Solomon, a former student, for allowing me to reproduce his poem on "The Conservation of Matter," called forth by my paper (No. 21) on "Domestic Science."

I am indebted to Professor R. A. Gregory and to Mr. A. T. Simmonds for advice in selecting and editing the articles for publication; and I owe the former very special thanks for the manner in which he has at all times placed his great technical knowledge at my disposal.

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I

THE TEACHING OF SCIENTIFIC METHOD

THIS title is chosen advisedly, in order to mark the contrast between the teaching of what is commonly called *science* and the teaching of *scientific method*: it is, I think, to the failure to discriminate between these that the delay in introducing experimental studies into schools generally of which we so bitterly complain is largely attributable.

For years past the educational world has been witness of conflicts innumerable: its time-honoured and most cherished dogmas and practices have been subjected to severely searching criticism and it cannot be denied that they have oftentimes emerged from the battle in a terribly mangled condition; nevertheless they have hitherto manifested a marvellous recuperative power. Modern subjects, especially experimental science, have as yet barely obtained a foothold in our schools and their educational effect has been scarcely appreciable—nay, it is even said, probably with too much of truth, that the results under our present—may I not say—want of system are inferior to those obtained in the purely classical days of yore when the scholars' efforts were less subdivided—when fewer subjects claimed their attention. The net upshot of

discussion has been simply that we are intensely dissatisfied with our present position and that we realise that some change has to be made. What that change is, we are not yet agreed. This, after all, is a very healthy state to be in and one which necessarily must precede the construction of a satisfactory programme of studies suited to the vastly changed conditions under which the work of the world has been carried on since those two potent agents, steam and electricity, have assumed sway.

In setting our house in order, one great difficulty arises from the multitude of counsellors: every subject in turn asserts its soul-saving power and puts forth its claim on a portion of the school time; an infinite number of suggestions are made—who is to arbitrate in so difficult a case? Certainly, the more I study the educational problem, the more I realise how extraordinary are the difficulties which it presents: we are not all cast in one fixed mould and cannot all be made alike; educational rules must necessarily be made infinitely elastic and educational success can only be achieved by the elastic administration of rules.

But are those who are charged with the conduct of so difficult a mission in any way specially prepared for the campaign? Suppose that at a largely attended representative meeting of British teachers some one were to discourse in most eloquent terms of the beauties of the Chinese language and were to affirm in the most positive manner possible that no other language offered the same opportunity of inculcating lessons of the highest import—what would be the result? Few, if any, present would know a word of the language; therefore, although all might agree that they had listened to a most learned and interesting

discourse, the effect would be ephemeral and the advice given would be wholly disregarded by the majority. Never having had occasion to study the language, probably they would mentally set down the lecturer as a doctrinaire—as a member of that troublesome and objectionable class, the enthusiasts, who are always interfering with other people's business and trying to lead them to mend their ways. Some few might think it politic to include Chinese in their school programme. These would either purchase a "Reader" and endeavour to master the subject themselves sufficiently to impress a smattering of information on a limited number of pupils in the higher forms in their schools perhaps; or they would engage as teacher a young fellow fresh from the University who had little more than mastered the principles of the Chinese alphabet but was considered capable of anything because he had taken a good degree. I very much fear that the treatment which I picture as accorded to my hypothetical subject, Chinese, is very much the kind of treatment meted out to experimental science in most schools. In the majority of cases, it has been included in the programme because it is become fashionable and is a subject in which public examinations are held; more or less under compulsion; without real belief in its worth or efficacy as an educational instrument. It is not surprising, therefore, that the results have been so unsatisfactory.

Two causes appear to me to operate in retarding educational progress. In the first place, with scarcely an exception, our schools are controlled by our ancient Universities. These, I think, are not improperly described as, in the main, classical trades-unions; the majority of those who pass through their courses are

required only to devote their attention to purely literary studies; unless by accident, they acquire no knowledge of the methods of natural science; consequently, having no understanding of, they exhibit no sympathy with, its aims and objects. It is a strange fact that so limited and non-natural a course of training should alone be spoken of conventionally as "culture" and that it should count as no sin to be blind to all that is going on in the world of Nature around us and to have no appreciation or understanding of the changes which constitute life—no knowledge of the composition and characters of the materials of the earth on which we dwell. As the entire body of teachers in the more important of our schools are University men and the example which such schools set permeates into and pervades schools generally, the result of the introspective system of training followed at our Universities is disastrous: that the effect of a change in the system on scholastic opinion and practice would be far-reaching has been clearly realised.[1]

But, beyond the difficulties created by the low standard of scholastic and public opinion as regards natural science, there is a second retarding cause in operation, for the existence of which we teachers of natural science are in a great measure responsible and which it behoves us to remove. I refer to the absence of any proper distinction between the teaching

[1] "I sometimes dream of a day when it will be considered necessary that every candidate for ordination should be required to have passed creditably in at least one branch of physical science, if it be only to teach him the method of sound scientific thought."—CHARLES KINGSLEY.

"If, twenty years ago, this University (Oxford) had said, from this time forward the elements of natural science shall take their place in Responsions, side by side with the elements of mathematics, and shall be equally obligatory, you would long ago have effected a revolution in school education."—DR. PERCIVAL (*circa* 1885).

of what is commonly called *science*—*i.e.* facts pertaining to science—and the teaching of scientific method. The dates at which our various kings reigned, the battles they fought and the names of their wives, are facts pertaining to history and it is not so very long since such facts alone were taught *as* history; nowadays, such facts are but incidentals in a rational course of historical study and it is clearly realised that the great object is to inculcate the *use* of such facts—the moral lessons which they convey. "And if I can have convinced you that well-doing and ill-doing are rewarded and punished in this world, as well as in the world to come, I shall have done you more good than if I had crammed your minds with many dates and facts from modern history" (conclusion of Kingsley's lectures on America at Cambridge in 1862) are words which aptly convey an idea of one of the chief purposes gained in teaching history and by which the methods of teaching it are being moulded. In like manner, to inculcate scientific habits of mind—to teach scientific method—we must teach the use of the facts pertaining to science not the mere facts. Again, in teaching history in schools, we recognise that the subject must be broadly handled and attention directed to the salient points which are of general application to human conduct; the study of minutiæ is left to the professed historian. But the very reverse of this practice has been followed, as a rule, in teaching natural science in schools. At various times during recent years—at the Educational Conference held at the Health Exhibition in 1884 and at the British Association meeting in 1885—I have protested against the prevailing system of teaching chemistry, etc. to boys and girls at school as though the object were to

train them all to be chemists; and I have also protested against the undue influence exercised by the specialist —an influence which he has acquired in consequence of the inability of the head of the school to criticise and control his work. I refer here as much to the examiner as to the teacher; indeed, more. It appears to me to be our duty to regard all questions relating to school education from a general point of view—to consider what is most conducive to the general welfare of the scholar; and in allowing the specialist access to the school, the greatest care must be taken that the subject treated of is dealt with in a manner suited to the requirements of the scholars collectively. It is only in the case of technical classes that supreme control can be vested in the specialist.

In order that we may be in a position to criticise usefully the educational work which is being done and the proposals brought forward, it is essential to arrive at a clear understanding of the objects to be achieved. Much of the work in a school is done with the object of cultivating certain arts—mechanical arts, we may almost call them: the art of reading, the art of writing and the art of working elementary mathematical problems—until the operations involved are efficiently performed in an automatic manner. An elementary acquaintance with these arts having once been gained, all later studies may be said to originate naturally in them—both those which lead to the acquisition of knowledge and those which have for their ultimate object the development and training of mental faculties. The character and extent of these later studies is subject to great variation according as individual requirements, opportunities and mental peculiarities vary; but the variation is not usually permitted to take place until a some-

what late period in the school career. We recognise, in fact, that in the case of every individual the endeavour must at least be made to develop the intellectual faculties coincidently in several directions. The question at issue at the present moment, I take it, is the number of main lines over which we can and are called on to travel. Hitherto only two have been generally recognised—the line of literary studies and the line of mathematical studies; but those of us who advocate the claims of natural science assert that there is a third and that this is of great importance, as a large proportion of the work of the world is necessarily carried on over it. We assert, in fact, that however complete a course of literary and mathematical studies may be made, it is impossible by attention to these two branches of knowledge to educate one side of the human mind—that side which has been instrumental in erecting the edifice of natural science and in applying science to industry: *the use of eyes and hands.* I never tire of quoting the following passage from Kingsley's lecture to the boys at Wellington College (*Letters and Memoirs of his Life*, 3rd abridged edition, p. 146; Kegan Paul & Co.); it puts the case into a nutshell:—

> The first thing for a boy to learn, after obedience and morality, is a habit of observation—a habit of using his eyes. It matters little what you use them on, provided you do use them. They say knowledge is power, and so it is. But only the knowledge which you get by observation. Many a man is very learned in books, and has read for years and years, and yet he is useless. He knows *about* all sorts of things, but he can't *do* them. When you set him to do work, he makes a mess of it. He is what you call a pedant, because he has not used his eyes and ears. . . . Now, I don't mean to undervalue book learning, . . . but the great use of a public school education to you is, not so much to teach you things as to teach you

how to *learn*. . . . And what does the art of learning consist in? First and foremost in the art of observing. That is, the boy who uses his eyes best on his book and *observes* the words and letters of his lesson most accurately and carefully; that is the boy who learns his lesson best, I presume. . . . Therefore, I say, that everything which helps a boy's powers of observation helps his power of learning; and I know from experience that nothing helps that so much as the study of the world about you.

Literary and mathematical studies are not a sufficient preparation in the great majority of cases for the work of the world—they develop introspective habits too exclusively. In future, boys and girls generally must not be confined to desk studies: they must not only learn a good deal *about* things, they must also be taught how to *do* things and to this end must learn how others before them have done things by actually repeating—not by merely reading about—what others have done. We ask, in fact, that the use of eyes and hands in unravelling the meaning of the wondrous changes which are going on around us in the world of Nature shall be taught systematically in schools generally—that is to say, that the endeavour shall be made to inculcate the habits of observing accurately, of experimenting exactly, of observing and experimenting with a clearly defined and logical purpose and of logical reasoning from observation and the results of experimental inquiry. Scientific habits and method must be universally taught. We ask to be at once admitted to equal rights with the *three R's*—it is no question of an alternative subject. This cannot be too clearly stated. The battle must be fought out on this issue within the next few years.

The importance of entering on the right course when the time comes that this claim is admitted—as it

inevitably must be when the general public and those who direct our educational system grasp its meaning —cannot be exaggerated. The use of eyes and hands —scientific method—cannot be taught by means of the blackboard and chalk or even by experimental lectures and demonstrations alone; individual eyes and hands must be actually and persistently practised from the very earliest period in the school career. Such studies cannot be postponed until the technical college or University is reached; the faculties which can there receive their highest development must not have been allowed to atrophy through neglect during the years spent at school. This is a point of fundamental importance. At school the habit is acquired of learning lessons—of learning things from books—and after a time it is an easy operation to a boy or girl of fair mental capacity, given the necessary books, to learn what is known about a particular subject. One outcome of this, in my experience, particularly in the case of the more capable student, is the confusion of shadow with substance. "Why should I trouble to make all these experiments which take up so much time, which require so much care and which yield a result so small in proportion to the labour expended, when I can gain the information by reading a page or so in such and such a text-book?" is the question I have often known to be put by highly capable students. They fail to realise what is the object in view—that they are studying method; that their object should be to learn how to make use of text-book information by studying how such information has been gained; and to prepare themselves for the time when they will have exhausted the information at their disposal and are unprovided with a text-book—when they will have

to help themselves. I am satisfied that the one remedy for this *acquired disease* is to commence experimental studies at the very earliest possible moment, so that children may from the outset learn to acquire knowledge by their own efforts; to extend infantile practice—for it is admitted that the infant learns much by experimenting—and the Kindergarten system into the school, so that experimenting and observing become habits. The vast majority of young children naturally like such work and it is to be feared that our system of education is mainly responsible for the decay of the taste with advancing years.

II

AN APPEAL TO HEADMASTERS

More than twenty years ago Matthew Arnold wrote: "The want of the idea of science, of systematic knowledge, is . . . the capital want . . . of English education and of English life." The same statement may be made to-day without fear of contradiction. And yet, during the latter part of our century, science has revolutionised the world and its charms as well as its claims on our attention have been eloquently advocated by a multitude of speakers. Arnold implied that the responsibility for the condition of affairs he deplored rested with our schoolmasters. It is to be feared that they have done little in the interval to exonerate themselves: if not obdurate in resisting change, they have at least made no proper effort to bring it about. Why is this?

A writer on China has remarked: "The contemplation of China is discouraging—to think it got so far so long ago and yet has got no further! The Emperor Hoang-li, who lived 200 B.C., may be supposed to have foreseen the deadening effect that government by literary men has upon a nation, for he burnt all their books except those that treat of practical arts." May not a clue to our failure to appreciate science be

found in this passage? For is it not the case that we are at the stage of being governed by literary men—that those who have the charge of the education of the youth of the country are nearly all literary men; that most of our youth are allowed to grow up as literary men; that our Parliament is full of literary men; and that our Press is a purely literary organisation?

Do we not pay so little attention to studies of "practical arts" as to justify the statement that they are disregarded by all but the very few among us? And are not the consequences very serious? As men of the world we must see that complaints are rife in every quarter; that there is a growing sense of public unrest; and we must all have felt that there is a screw loose somewhere. And those of us who go abroad and who notice how effectively the forces of some other nations are being organised are not only oppressed with anxiety but even with a deep sense of shame, that we should remain so callous to our own shortcomings. Is it not time that the warning given by the shade of Matthew Arnold should no longer be allowed to fall on deaf ears? Should not schools generally co-operate in removing the stigma and inculcate "the idea of science" in the minds of all their scholars?

It is to be feared, however, that "science" is the subject with which those who have charge of our schools are least acquainted. Nor is it surprising that this is the case, as the majority of men who graduate either at Cambridge or at Oxford are not required to study any branch of "science." Whatever the cause, being unacquainted with the subject, it is difficult for most teachers to understand its methods and appreciate its value or to understand why so

much "fuss" is made about its importance by some of us; why we are so aggressive in insisting that science should not only be introduced into the school curriculum but that it should be accorded a position of prominence and real importance.

Carlyle has well said that no character has ever been rightly understood till it has first been regarded with a certain feeling not of tolerance only but of sympathy. This is equally true of subjects—only sympathy begotten of understanding will lead those in charge of schools to welcome and introduce new methods. Until such sympathy is engendered teachers will be swayed hither and thither by the breath of fashion and there will be no fixity of opinion as to what is desirable. In order to enlist such sympathy it is necessary to speak very plainly, as it is most desirable that a clear understanding should be arrived at without delay and that all should realise that they have a common purpose in view.

In the book on China referred to, a memorial is reproduced which was addressed to the Emperor by Prince Kung a short time ago on the establishment of a college for the cultivation of Western science: in the course of this the Prince remarks: "A proverb says 'A thing unknown is a scholar's shame.' Now, when a man of letters, on stepping from his door, raises his eyes to the stars and is unable to tell what they are, is not this enough to make him blush? Even if no schools were established, the educated ought to apply themselves to such studies." Bearing in mind the respect we pay to Chinese institutions—as shown in our adoption of their system of literary examinations as a condition of entry into our Civil Service—and that we are at the present time engaged,

through the agency of various public examining bodies, in seeking to compel the nation generally to adopt the system, we might surely go a stage further and accept the wise direction of an enlightened Chinese statesman when he reminds us that a thing unknown is a scholar's shame.

We gibe at the intense conservatism of the Boers but the beam in our own eye is unnoticed, for we forget, or cannot realise, how absolutely similar our condition is to theirs and that—taking our opportunities into account—we are far ahead of all other nations in our disregard of the teachings of experience. It has been stated that the Boer has seen his country developed against his will and without his collaboration; but our country is being developed, if not against the will of our schools, at all events without their direct and thorough collaboration, in so far as the applications of science are concerned.

It behoves us, then, to inquire wherein our methods are faulty—what are to be regarded as sound methods. In his shilling manual *Aids to Scouting*—a book which every teacher should own and study as being one of the few dealing with the "practical arts" which will be worth preserving when text-books generally are destroyed by edict—Baden-Powell tells us that "the main key to success in scouting is to have pluck, discretion and self-reliance." Surely these qualities are the key to success in everything! Pluck, he says, in its highest form—viz. that of the unassisted individual—is very much the result of a man's confidence in himself. And confidence in yourself you can only have, he adds, when you know that, by training and practice, you are thoroughly up in the work that you have to do. Self-reliance he defines as the ability to

act "on your own hook"—to be able to see what is the right line to take, according to circumstances, without wanting some one at your elbow to tell you exactly what to do.

Of course, all will agree with this; but can we assert that we in any way train boys and girls *in school* to exhibit such pluck, discretion and self-reliance? I venture to say that we cannot. Instead of being self-reliant, discreet and full of intellectual pluck, our modern boys and girls are made absolutely dependent on their teachers and on text-books; they have scarcely an idea of their own except on topics which have not been touched upon *in school;* they have no healthy desire to increase their intelligence. It has been my lot, during the past thirty years, to act as teacher of all sorts and conditions of boys and of some girls after they have left school. I have also served in very nearly every possible field as an examiner. I cannot think that the experience which has forced this painful conclusion upon me is at all a peculiar one.

No words are strong enough to express our appreciation of the magnificent bravery and dash shown by all ranks in the present (S. African) war; but the recognition of the existence of such wonderful qualities in our soldiers makes our grief at the terrible losses we have suffered all the deeper, when we reflect on the many and clear proofs which have been given of the absence of proper thoughtfulness and of the failure to apply scientific method. It is clear that to win our battles in the future preparations must be made in the school workshop rather than in the playing-fields. In fact, scientific method *must* be introduced into schools in order that some preparation may be given for successful scouting in the world and to obviate the natural

powers remaining so undeveloped that experience has to be gained painfully and almost entirely by undirected self-effort after school is left.

Baden-Powell's book is full of good advice which is applicable to ordinary training. Take, for example, his instructions on reporting:—"Only report facts, not fancies. That is to say, in describing, say, a river, don't call it a 'large river'—that may mean anything—but give its apparent width and depth in yards and feet as nearly as you can judge. Similarly, 'a large body of the enemy' conveys no meaning—it might mean a squadron or it might mean a division." Nothing could be more admirable than this direction to report facts, not fancies. It is what we insist on in all scientific work; it is what is required in the world by all employers who rely on their assistants for information; but the art is one which is never learnt at school.

In pointing out how to practise in peace times, he strongly recommends would-be scouts to read *The Memoirs of Sherlock Holmes*, by Conan Doyle, and see how, by noticing a number of small signs, he "puts this and that together" and gathers important information. This, again, is precisely our method—the scientific method: in fact, I have for years past urged upon my students that the method adopted by the detective is that of the scientific worker and the only possible one to adopt in studying science as a mental and moral discipline. If heads of schools will but regard science from such a point of view, they will have little difficulty in understanding its importance and value as an essential factor in education; they will then also understand the spirit in which it must be taught to be of use in schools.

The main object of introducing science into schools, however, *must be* to develop character on its practical side with the purpose of teaching our youth to scout in the world—to use their eyes, to draw correct inferences, to be guided by what they see and to help themselves. From this point of view the study of method is alone of importance; it stands to reason, however, that in studying and acquiring a useful knowledge of method a knowledge of facts is necessarily also acquired.

But a revolution must be effected in our schools if scientific method is to be taught in them. I have no hesitation in saying that at the present day the so-called science taught in most schools, especially that which is demanded by examiners, is not only worthless but positively detrimental. All who are acquainted with the facts know this to be the case; and if we ask ourselves the simple question—whether what is done tends to develop the wits, to develop the power of self-help, we must all admit the very opposite to be the case. Schools, in fact, are engaged in fashioning our youth to require leaning-posts, not in training them to act on their own account; examinations have made self-help impossible. No employer, go where you will, is satisfied with the product the schools turn out.

Speaking to headmasters, I would say that on them mainly rests the heavy burden of *demanding* a reform, as they are, in a measure, responsible for having allowed an altogether improper condition of things to grow up. I recently ventured to remark, in a discussion at one of the Educational Conferences held at the beginning of the year at the Imperial Institute, that "headmasters suffer us but do not love us."

They have, in fact, admitted the science teacher into their schools because they saw that he was getting into fashion; but they have had no sympathy with his work; and having made no attempt to understand his methods, unfortunately have allowed him, within the time at his disposal, to do pretty much as he pleased. Having never received any pedagogic training, he naturally follows the example set him by his teachers: he proceeds to teach on professional lines, as though the boys under him were going to be chemists or physicists; it never occurs to him that education and professional training are two very different things.

The situation is made worse by the fact that our system of professional training is thoroughly bad, no proper attempt being made to infuse feeling into it nor to impart a knowledge of true scientific method. The difficulty has arisen because few teachers give any thought to method. Most teachers, therefore, have never been trained to think broadly; they have no desire to scout even within their own proper domain; the spirit of research has never entered into their lives—consequently they are almost powerless to act alone and incapable of originating.

There is but one way of effecting the necessary changes: that is to reform the Universities, whence the supply of teachers is derived. Directly or indirectly they govern everything. This could be done within a generation, if headmasters would but agree to make the demand—by the Universities requiring proper proof of some appreciation of scientific method to be given by all candidates for admission, which would make it necessary for all schools to give proper training in scientific method; and by their insisting

that the spirit of research shall dominate the entire course of training. The theory at the Universities at present is that a man must be well read—that he must know all that other people have done—before he even thinks of doing anything himself. Only graduates are allowed to scout—to do research work; consequently, the majority escape without any taint of *acquired* intelligence whilst those who undertake research work as a post-graduate exercise are frightfully hampered by a burden of knowledge much of which is useless—because the power of using it has never been inculcated and self-reliance has never been taught.

Whilst making these demands of the Universities, the schools must be prepared to make great changes. Far less attention must be paid to books and to set lessons; far more attention must be given to practical studies conducive to the formation of habits of self-reliance. Boys and girls must learn to think and act for themselves, to utilise the knowledge they have and to know how to increase their knowledge. To this end they must be taught "to think in shape," as Thring puts it; to work with the tangible. And they must be so trained from the very earliest age—it is the falsest policy possible to waste the early years of extreme youth—when the acquisitive faculties are so exceptionally developed—and to allow wrong ideals to become established, as these can never afterwards be got rid of. As to the possibility and desirability of so training boys and girls, I will quote only one opinion; but as that was given more than a century ago by one of England's greatest discoverers, Priestley, it may both serve to justify my argument and to show that it is sufficiently old-fashioned to be worthy of

adoption. It is to be found in the preface to his collected works, published in 1790:—

I am sorry to have occasion to observe that natural science is very little, if at all, the object of *education* in this country, in which many individuals have distinguished themselves so much by their application to it. And I would observe that, if we wish to lay a good foundation for a philosophical taste and philosophical pursuits, persons should be accustomed to the sight of experiments and processes *in early life*. They should more especially be early initiated in the theory and practice of *investigation*, by which many of the old discoveries may be made to be really *their own*—on which account they will be much more valued by them. And, in a great variety of articles, very young persons may be made so far acquainted with everything necessary to be previously known, as to engage (which they will do with particular alacrity) in pursuits truly original.

I believe that school-work will be carried out on much less formal lines in the future than it has been in the past and much more in accordance with the plan which is followed out of school. Out of school we do not, as a rule, engage in some fresh task once an hour but we undertake some set piece of work and carry it through, all the various incidental operations being performed as the necessity arises. The experiment must at least be made of applying this system to the teaching of scientific method in schools. *Problems* must be set and time must be allowed for their solution; class-rooms must either be converted into workshops or ample workshop accommodation must be provided. I advisedly do not speak of laboratories, as the word has an un-English sound and is offensive to classical ears.

So soon as it is recognised that the literary side is only one side of school-work no objection will be raised to this. But there must be no disregard of the literary side—in fact, it must receive far more care

and attention than is at present accorded to it. My great complaint as a professor at an engineering college, in fact, is not that students when they join us are ignorant of science and incapable of undertaking any practical exercise requiring independent action and thought—for that I take to be a matter of course—but that, as a rule, they are incapable of writing out any proper record of the work they do. This is because they have never had any practical training in such work: the kind of exercise they have been called on to do at school being of an entirely unpractical and inexact character.

As an example of the work of the rationally organised school of the future, let us assume that a boy has been set to solve some simple problem and that this involves much experimental work: he should nevertheless be required first to write a description of what he is about to do in which the motive by which he is guided is clearly stated. He would receive his instructions in the workshop and—if there were not room in the workshop—he might then go to the class-room to do this writing; and when his statement had been approved by the workshop instructor, he would carefully copy it out in the notebook in which the history of his researches is to be finally recorded. Then—but only then—he would proceed to make experiments. If it were necessary, in fitting up the apparatus he required, to do any carpenter's or smith's work, he would incidentally get a lesson or gain practice in such work. When the experiment was made, an account of the results would be written up and conclusions drawn: this might give rise to arithmetical work or a drawing or photograph might be required to illustrate the account, some question

of grammar or philology might arise. Incidentally, therefore, teaching would be given in a variety of subjects; several teachers might take part in the work and it would be the duty of the directing instructor to see that the proper opportunities were provided for them all. Under such a system boys would become handy and able and willing to help themselves in all sorts of emergencies. Their interest would no longer be confined to athletics. Girls would benefit even more than boys.

Present-day teachers will be horrified by this picture of a school of the future; but in common with many others I feel that we are at a critical period and that it is a duty to speak out and seek to be constructive. The Chinese system of government by literary men is clearly a failure, not only in China but also in this country; and as progress is effected in these days not at mail-coach and sailing-vessel speeds but at the far quicker rates rendered possible by steam and electricity, we can no longer afford to await development—we must force it on if we perceive it to be necessary and inevitable.

Our present position is somewhat as follows: All are agreed that the one great object to be effected by education is the due development of the faculties generally. Those who live sufficiently in the world are aware that, however admirably and fully classical training may serve its purpose in developing some of the faculties, others of at least equal importance remain untutored unless the methods are resorted to which science and science only places at our disposal. Honest educators cannot any longer rest satisfied in merely following the course laid down by their forefathers—they must march with the times. Naturally

they find the position strange and difficult but it is none the less their duty to endeavour to solve the problem presented to them; and to this end they must seek to show sympathy with those whom they have too long treated with the coldest indifference, if not with contempt—and who yet bear them no malice.

We must awaken to the fact that, as Thring puts it, the whole human being is the teacher's care; and that to cut the child in half is a deadly sin.

III

THE FUTURE WORK OF THE SECTION OF EDUCATIONAL SCIENCE

THE formation of a new Section of the British Association, devoted to Educational Science, at the opening of the century, is properly regarded as an event of no slight importance and significance.

If it carry out the desires of its promoters—as we may fervently hope will be the case—at no distant date, it will be one of the most valuable Sections of the Association: that in which all the others, in a sense, will have their origin and to which they will gratefully tender the fruits of their experience. Indeed, expression has been given to this feeling—that the most intimate relationship should be recognised between it and all the other Sections of the Association—in the step taken by the Organising Committee in inviting each of the other Sections to send a delegate to serve on the Sectional Committee, a procedure without precedent, which should give to the Committee an unusual degree of weight and importance.

It will be the function of the Section to deal with the science of education—not merely with science *in* education. In other words, it will be devoted to the scientific treatment of education *in all its branches*;

its object will be to introduce scientific conceptions into every sphere of educational activity. Science, however, is a word too often supposed by the general public to have a very limited meaning and is much misunderstood—it will be well, therefore, to emphasise the fact that to use the word scientific is after all but to imply a thorough and exact treatment of a subject, a treatment involving full knowledge and understanding.

For the first time, a public platform has been provided on which the subject matter and methods of education can be fully and impartially discussed without reference to personal or political considerations. The Section has been instituted at the instance of a body whose main care hitherto has been the interests of natural science: a body in which humanistic studies have played no part. The Association now invites those to join its ranks who have been accustomed to regard the humanities, if not as the only fit subjects of study, at all events as affording a sufficient basis of a general education: we deny this premise and we ask them to consider fully with us the programme of the future. It is essential that they should be well represented at the meetings—although attendance may demand some sacrifice on their part just as it does on ours at the present time. Fortunately, the Assistant Masters' Association, mindful of the importance of the opportunity, has formally delegated two of its members to attend the meeting. The example is one worthy of imitation, which we may hope those august beings, the Headmasters, will in time follow. The public will surely expect that when the methods of education are being seriously debated those to whom the care and conduct of education is mainly intrusted shall con-

tribute their full share to the inquiry. They cannot be regarded as such past masters of their art that they can afford to withdraw themselves from the vivifying influences which abound at the meetings of the Association. In fact, teachers are all bound to recognise that they are but learners in the art of teaching—that they live in new times and must adopt new practices—and that the public good requires that they should cordially co-operate in introducing the changes which so many see are necessary but which so few can define.

To consider the work of the Section. In addressing it, the President, Sir John Gorst, has told us "that the power of research—the art of acquiring information for oneself—on which the most advanced science depends, may by a proper system be cultivated by the youngest scholar of the most elementary school." The extraordinary advance in opinion which these words mark need scarcely be pointed out. Indeed to have elicited such an expression from a Vice-President of the Board of Education is almost a sufficient justification of the establishment of the Section. But the public have yet to understand the meaning of the word research and its infinite importance; that the power of research—the art of acquiring information for oneself, aye, and of making use of it too—not only may, as the President said, but *must* be cultivated in all, as it is the power on which advance in life depends.

It will be the great work of the Section to teach this doctrine. And first of all we must impress it on teachers generally. Why is it that the British Association has taken so active a part in educational discussions during recent years and that its members have so often played the part of reformers? It is

because they are dominated by the spirit of research. The humanists are too often satisfied to study what has been; but we feel that we must go forward: true teaching will be universal only when teachers generally are actuated by this spirit. We hear much—too much—of the superiority of the German educational system to the English. Such superiority as there is arises in part from the thoroughness with which the work is done in the German schools: but especially from the fact that the Germans have made research—the power to extend the boundaries of knowledge—the corner-stone of their educational edifice whilst we have not yet learnt to mention it even in the specification. Respect is paid to the University graduate in Germany because it is felt—the public feel—that he has penetrated some little way into the Holy of Holies: that he has striven to attain to an ideal and in some degree cultivated his imaginative power.

It will be the function of the Section gradually to shape a science of education—for we certainly cannot speak of one as existent at the present day. No little time and labour must be devoted to the task, if it is to be raised to the dignity of an exact science within a reasonable period.

There are two great questions which it seems to me need immediate consideration: the preparation of a national programme of education and the training of teachers—the latter being dependent on the former, as an understanding must be arrived at as to the work to be done before the preparation for that work can begin.

The need of a national programme should be obvious. It is a necessary preliminary to the organisation of our educational system. We must without much further

loss of time determine what are the essential elements of a liberal training in each of the various grades. The weary struggle which has gone on for years, the conflict of opinion which exists, must be terminated: they can have no justification in fact at the present day; the uncertainty we feel can only be, in the main, the outcome of our failure to submit the problem to scientific treatment. Indeed the extraordinary vagueness of the propositions brought forward by most of the would-be reformers of the day is probably the best proof that a programme is needed.

The cruel treatment accorded to boys in the schools which lay themselves out to prepare for the big public schools has been laid bare in the recent report published under Mr. Sadler's direction by the Board of Education. Such a travesty could never be allowed to rank as education if we had a proper programme. It would then be impossible for the big schools to exercise a demoralising influence on the preparatory schools or for the Universities in any way to tempt the big schools to depart from the right path. The schools will never escape from the vicious circle in which they at present work until a programme is laid down for public guidance and some watchful care is exercised to see that its provisions are respected: except under the force of public opinion, the schools will make no concessions; and to form public opinion an authoritative decision must be arrived at.

The existing body of teachers in schools, however, cannot alone prepare a rational programme. Their training has been too one-sided. The humanists, in fact, are lacking in sympathy and sense of proportion and have neither the knowledge nor the breadth of imagination required for the task. They must there-

fore enter into alliance with the realists, as they are commonly termed, who however are better spoken of as naturalists—their main object being to secure due attention to the study of Nature and the due development of all the human faculties, not of the mind alone.

And the alliance must be on equal terms. A constitutional government must be substituted for an absolute autocracy.

We are undoubtedly on the eve of a general revolution in education—one which will lead to the public recognition of the fact that our system is entirely one-sided. It cannot much longer happen that we who are accustomed to rate ourselves a practical people will allow our schools to be conducted in such a way that the development of the practical faculties is almost left out of account; or that we will continue to allow our boys and girls to be kept sitting at desks almost all day long and during several hours in the evening. We must demand that the preparation given be a real preparation for the multifarious duties of life; that bodily as well as mental activity be duly developed; that there be some return to the old Greek ideals. The establishment of the new Section may be regarded as in a measure the first public outbreak of the revolt; for the first time, the scattered forces of the educational army are about to be organised; for the first time the party of reform is about to make good its right to be heard.

No slight change in the programme will give us what we require: a radical change in procedure must be made. The reform will probably come through the introduction of workshop and laboratory methods. It has to be made clear that a large proportion of time must be given to such work—not a miserable two or

three hours a week, as at present. But this is not the occasion to go into details; these will have to be settled in laying down our programme.

There is no doubt that the fight will be over the granting of its proper place to what is commonly called science. The action taken by the Association in early days is worth recalling at the present time. In 1868 it issued a report on the best means of promoting scientific education in schools. From the preface to this report, it appears that the importance of introducing Natural Science into the higher schools of this country was brought before two sections of the meeting of the British Association at Nottingham, in 1866; and that a proposal to appoint a Committee for the purpose of considering the best method of extending scientific education in schools was referred to the Council of the Association. At a meeting of the Council, held on November 15, 1866, a Committee was appointed for the purpose of inquiring into the subject. This Committee consisted of the General Officers of the Association, the Trustees, the Rev. F. W. Farrar, M.A., F.R.S., the Rev. T. N. Hutchinson, M.A., Professor Huxley, F.R.S., Mr. Joseph Payne, Professor Tyndall, F.R.S., and Mr. J. M. Wilson, M.A. A report drawn by the Rev. F. W. Farrar, Mr. G. Griffith, Professor Huxley, Professor Tyndall and Mr. J. M. Wilson and revised by the Committee, was presented to the Council and received by them on March 9, 1867. At a subsequent special meeting the Report was considered by the Council and it was resolved to adopt the recommendations and to submit the Report to the General Committee of the Association. At the meeting at Dundee, September 1867, the Report was received by the General Committee and the following Resolution

was passed :—"That the President of the Association be requested to communicate the Report of the Committee appointed by the Council to consider the best means for promoting Scientific Education in schools to the President of the Privy Council and to the Parliamentary Committee, on the part of the Association, and that the General Officers be authorised to give publicity to the Report.

The reasons given in this Report why general education in schools ought to include some training in science are as follows :—

"As providing the best discipline in observation and collection of facts, in the combination of inductive with deductive reasoning and in accuracy both of thought and language.

"Because it is found in practice to remedy some of the defects of the ordinary school education. Many boys on whom ordinary school studies produce very slight effects are stimulated and improved by instruction in science; and it is found to be a most valuable element in the education of those who show special aptitude for literary culture.

"Because the methods and results of science have so profoundly affected all the philosophical thought of the age that an educated man is under a very great disadvantage if he is unacquainted with them.

"Because very great intellectual pleasure is derived in after life from even a moderate acquaintance with science.

"On grounds of practical utility as materially affecting the present position and future progress of civilisation."

It would be difficult to state the case more clearly at the present day, although in the interval a consider-

able change in attitude has taken place, the teaching of the ABC of *scientific method* rather than of any branch of science being now advocated as essential; and an almost general consensus of opinion has been arrived at, that the work must be done by the scholars individually and at least mainly on what are known as heuristic lines. The Association has had a most important influence in bringing about the introduction of rational methods of teaching through the reports presented in 1888-1890 to the Section of Chemistry; and the success of these Reports has proved how great an influence the Association may exercise if it only take the pains to advise constructively: the failure of the 1867 Report to effect the desired change is doubtless due in a measure to the absence from it of constructive proposals — teachers have been so ill prepared to teach that they have needed to be told precisely what things to do and how to do them and it has been useless to give them advice in general terms. There is little doubt that if this Section desire to succeed it must adopt a constructive as well as a progressive policy.

When every allowance is made for the improvements effected, the sad fact remains that the schools still at most suffer science: they do not love it, except in rare cases; it would have but a lingering existence were it not for the money grants dispensed by Government. The ancient Universities do not regard even an elementary knowledge of scientific method as a necessary element of culture. We are in reality as slow to learn our lesson, as much behind the times, as China is in assimilating western civilisation. The failure is in our leaders—it might so easily have been otherwise had those in high places known how to lead

properly. During the past thirty years Japan has entirely reformed her system and has made the highest forms of Western knowledge her own since Huxley, Tyndall and others urged on the country through the British Association the importance of giving training in science; but the ears even of our Privy Councillors were deaf, the advice is still practically neglected and its importance in no wise appreciated. Japan has had wise leaders and the nation has been able to appreciate them.

It has been my lot during the past year to hear much said by cultured men and women about the training of teachers—and I am aghast at the narrowness of purview they have shown. That some attention might well be given to the study of scientific method and to practical exercises if time could be found, is apparently admitted by all; yet but few see that such study is an *indispensable* element in education. They fail to understand the practical needs of the world of to-day—having themselves had no practical training.

We have to make it clear to the public that it is not a question of teaching this or that particular branch of science — but of giving training in the ABC of scientific method, of making all education scientific: with the object of putting thinking heads on the shoulders of the rising generation; of so training our children that they learn to use their eyes and that all their faculties may be developed.

As Rudyard Kipling has recently said, "We have had no end of a lesson"—but whether, as he proceeds to add,—"it will do us no end of good" remains to be seen. It would almost seem that the lessons administered to us have but a passing effect and that

to keep alive the spirit of reform is almost impossible. However, again to quote Kipling—

"The more we work and the less we talk, the better results we shall get."

Let this be the motto of our Section. Our work will be mainly done during the intervals between the meetings. The meetings will serve to put on record what we have done and to make arrangements for future work, besides enabling us to come personally into contact and affording invaluable opportunity of removing misconceptions.

IV

ADDRESS TO THE EDUCATIONAL SCIENCE SECTION OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, BELFAST 1902

> This spiritual Love acts not nor can exist
> Without Imagination, which, in truth,
> Is but another name for absolute power
> And clearest insight, amplitude of mind,
> And Reason in her most exalted mood.
>
> WORDSWORTH—*The Prelude.*

THE meeting of the British Association at Belfast in 1874 was presided over by Professor Tyndall, one of whose most memorable discourses was that delivered at Liverpool in 1870 on "The Scientific Use of the Imagination." In the course of his Address the President could point out that "science had already to some extent leavened the world": abundant proof has since been given that he was right in claiming that "it will leaven it more and more." Nevertheless, if we consider the leavening effect which science has had on the public mind, it is impossible to deny that progress is being made in this direction at a woefully slow rate, in no way proportionate to the growth of knowledge or to the recognised usefulness of the many discoveries which are the outcome of scientific investi-

gation. Science is still treated by society as a rich *parvenu* all the world over and is at most invited to its feasts but not incorporated, as it should be, with the domestic life of the people.

Complaint has long been rife that the British are indifferent as a people even to things of manifest importance which as a nation of business men they might be expected to value. It would certainly seem that we are all too forgetful of Tyndall's warning that "every system which would escape the fate of an organism too rigid to adjust itself to its environment must be plastic to the extent that the growth of knowledge demands." As our President said a full quarter of a century ago, "when this truth has been thoroughly taken in, rigidity will be relaxed, things not deemed essential will be dropped and elements now rejected will be assimilated. The lifting of the life is the essential point and as long as dogmatism, fanaticism and intolerance are kept out, various modes of leverage may be employed to raise life to a higher level."

But how are we to become plastic to the extent that the growth of knowledge demands, in order that rigidity may be relaxed, that conservatism may give way to a wise spirit of advance? Probably there is no more important question the nation can ask at the present time: for that we are wanting in plasticity is proved to demonstration. Does not the shade of our former President stand before us and solemnly give answer: "By the cultivation and exercise of imaginative power—by the scientific use of the imagination"; for in these days are we not indeed a people "of little faith"? There would seem, in fact, to be clear evidence, if not of destruction, at least of impairment,

of imaginative power under modern conditions—that the tendency of education is to kill rather than to develop the very power on which the progress of the world depends. A dearth of imaginative power is strikingly apparent in art, in literature, in music, in science, in public taste generally, the prevailing tendency being to imitate rather than to originate and individualise. Commentators and critics of sorts abound but these rarely display any catholicity of judgment. Leaders are few and far to seek. The prevailing policy is that of the party in power—and more often than not of a caucus behind it—not the policy which on broad general grounds is the most desirable; in fact, little attempt is made to discover in any scientific manner what would be the really wise policy to pursue. Nothing could illustrate this better than the state of chaos into which affairs educational are plunged at the present time. Those who dare to differ or offer advice are looked at askance and always with jealous eyes; too often also everything is done to block the way of the reformer, not from any base motive but as a rule from sheer inability to appreciate what is proposed—from sheer lack of imaginative power. Necessarily, as the conditions of civilisation become more complex, the tendency to accept and follow must become greater, self-satisfaction more and more complete and general: unless effective means be taken to counteract such a tendency, decay is inevitable.

The phrase "creatures of habit" is familiar to us all: few will deny that we are seldom otherwise than creatures of habit, that plasticity of mind is a rare attribute. But the growth of knowledge is taking place at such a compound interest rate that a high degree of plasticity is essential if we are to avail our-

selves thereof. We were formerly accounted a nation of shopkeepers—of clever shopkeepers—but now the title is passing from us to the Germans and Americans, because they are more alive than we are to the fact that in these days it is necessary both to organise and to be alive to every opportunity. If we would put money in our purse in future, it will be necessary to put imagination into our affairs, so that we may be far more ready to act than we have been of late years.

And not only is knowledge increasing but our responsibilities are daily becoming heavier and heavier. In the minds of thinking men at the present time the burden of empire our nation bears is of appalling magnitude: the men who have imaginative power are aghast at the flippant unconsciousness of responsibility manifest in the public at large and even in the majority of our statesmen and politicians. It is widely felt that a deeper sense of responsibility must be induced among us, if we are to maintain our heritage intact—if we are to remain worthy to play the great part for which by an inscrutable ordinance we find ourselves cast at the very commencement of a new century. Nothing is so sure as that if we cannot show ourselves to be worthy we shall not long be allowed to play the part: jealousy confronts us on all sides; and we have learnt that the struggle for existence is Nature's first law, against which philanthropy is powerless so long as it be not universal—a contingency which is not even remotely possible. It is little short of remarkable that we should be able to go so far as we do in securing the services of able men to conduct our affairs generally; but we cannot be too mindful of the duty incumbent upon us of developing the store of ability

latent in the nation and above all of maintaining intact our heritage of individuality.

The call to organise the forces of our empire is imperative but we do not heed it in any proper manner. For many years past we have rarely refused to treat with utmost consideration the representations of those who have dwelt on the importance of our Navy. One of the most highly respected men in the country at the present day is our gifted American cousin, Captain Mahan, on account of the way in which he has exercised his powers of imaginative insight and taught us to understand our achievements at sea, to appreciate the true meaning and value of sea power. We need a Mahan to discuss the larger issues of national defence through education, to teach the nation the true meaning and value of education. The Ship of State is of vastly greater consequence than the mere Navy: yet those who direct attention to the insufficient character of its armament are scarce listened to; not the slightest effort is made to secure for it a scientifically adjusted and organically complete machinery for the effective administration and working of all its departments; the drill of its crew is woefully incomplete; what is worse, there is a terrible absence of organisation and discipline, a terrible absence of willingness, little if any desire to co-operate among those who are charged with its care; and the consequences of neglect are not immediately obvious. In war we appreciate the effects suddenly: a long list of killed and wounded brings its meaning home to us at once; we know that we must pay the penalty of defeat forthwith; the indemnity exacted can be expressed as a lump sum. The battle of life is waged in a less obtrusive way, the killed and maimed are

not scheduled in any regular manner; and so it escapes our notice that in reality the carnage is awful, that few if any escape without severe wounds, that defeat is constant and yet often dealt so silently and imperceptibly that it excites little comment. But we know that vastly more than is done might be done to alleviate if not to prevent suffering and even to give charm to life where at present there is but pain, if only our efforts could be organised. If we reflect on the bareness of the life lived by the majority, on the debasing conditions under which very many are placed, on the terrible evils consequent on indulgence in drink—surely we must agree with Tyndall that the essential point is to raise life to a higher level, to elevate the general tone of thought; that it is our duty to consider more seriously than we have done hitherto what use can be made of the forces at our disposal for the purpose.

If we will but picture to ourselves how most of our difficulties and especially our slow advance are consequences of lack of imaginative power, or perhaps rather of failure to exert the power which, though latent in most of us, is not sufficiently called into being by practice; if we will but consider how much of our success has been due to the exercise of imaginative power: we may be led to propound a fruitful theory of education, a theoretical basis on which a sound educational structure may be reared. It has been well said by Carlyle "that all that man does and brings to pass is the vesture of a thought." In fact, the illustrations which may be given of the value of theoretical conceptions, of imaginative power, are innumerable. Taking recent events, if we consider the success achieved by the late Mr. Rhodes, the

narrow-sighted will say he was a practical man: a man who did things and led others to do. Those with broader views recognise that at heart Mr. Rhodes was a theorist, an idealist, a man of imagination—hence his success. And men such as Lord Roberts and Lord Kitchener, whose immense services to the nation have been so universally admitted of late, are not merely practical soldiers of experience but men gifted with powers of insight and imagination—men able to apply theory to practice. Some of those who were unsuccessful in the late campaign are currently reported to have gone out to South Africa openly deriding science: it will be well if the lesson taught by their failure be not disregarded by their colleagues. The importance of the part played by theory in science cannot be exaggerated. We have only to think of the influence exercised by the Newtonian theory of Gravitation, by the Daltonian theory of Atoms, by Faraday's conception of Lines of Force, by the Wave theory in its varied applications, by the Darwinian theory of Evolution; we have only to think of the way in which the reflections of one weak man indited at his study-table in a secluded Kentish village have changed the tone of thought of the civilised world. Such theories are the very foundations of science: whilst facts are the building stones, theories furnish the design; and it is the interpretation of facts in the light of theory—the considered application of theory to practice—that constitute true science. The marvellous development of scientific activity during the past century has been consequent on the establishment of fruitful theories. If teachers generally would pay more attention to theory, their teaching would doubtless be more fruitful of results: facts they know

in plenty but they lack training in the considered use of facts. False prophets among us have long taught the narrow doctrine that practice is superior to theory and we pretend to believe in it. That the belief is founded on misconception may safely be contended, however: the two go together and are inseparable. It is true that we have enjoyed the reputation of being a practical people and have been accustomed to take no little pride in the circumstance, to scoff somewhat at theory: but behind our practice in the past there was a large measure of imaginative power, of theoretical insight; in fact, we were successful because we were innately possessed of considerable power of overseeing difficulties, of grasping an issue, of brushing aside unessential details and going straight to the point: in other words, of being practical. We are ceasing to be practical because modern practice is based on a larger measure of theory and our schools are paying no proper attention to the development of imaginative power or to giving training in the use of theory as the interpreter of facts: didactic and dogmatic teaching are producing the result which infallibly follows in their wake: sterility of intellect.

Mr. Francis Darwin, in his Reminiscences of his father, tells us that "he often said that no one could be a good observer unless he was an active theoriser." And he goes on to say: "This brings me back to what I said about his instinct for arresting exceptions: it was as though he were charged with theorising power ready to flow into any channel on the slightest disturbance, so that no fact, however small, could avoid releasing a stream of theory, *and thus the fact became magnified into importance.* In this way it naturally happened that many untenable theories occurred to

him; but fortunately his richness of imagination was equalled by his power of judging and condensing the thoughts that occurred to him. He was just to his theories and did not condemn them unheard; and so it happened that he was willing to test what would seem to most people not at all worth testing."

In his Autobiography Darwin remarks:—"I have steadily endeavoured to keep my mind free so as to give up any hypothesis, however much beloved (*and I cannot resist forming one on every subject*), as soon as facts are shown to be opposed to it." The italics in these passages are mine.

Our system of education has no proper theoretical basis. Educators have ceased to be practical because they have failed to keep pace with the march of discovery, the theoretical basis underlying their profession having been enlarged so rapidly and to such an extent that it is beyond their power to grasp its problems. The priesthood of the craft are, in fact, possessed by the spirit of narrow parochialism: they are upholders of an all too rigid creed, being lineal descendants of a privileged class—"the knowledge caste," to use Thring's expression—whose functions were far more limited than are those which must now be discharged by teachers if teaching is to be given which will serve as an efficient preparation for life under modern conditions. They enlarge *ad nauseam* on the superiority of literary and especially of classical training, forgetting that their preference for classics is but the survival of a practice and that their arguments in defence of a literary system are but preconceived opinions. Being incapable of appreciating the arguments used on the other side, it is unlikely that they will ever be able to admit their force.

So long as the forces of Nature were not tamed to the service of man, they could be neglected; sanitary sins were alone found out and punished with unsparing severity. But now it is otherwise. To succeed in competition with others we must be able to avail ourselves of every opportunity; and wide understanding is demanded of us. Moreover the growth of knowledge has induced severe mental hunger; the feeling that the dainty dishes provided by Nature should be in no selfish manner restricted to the few is a growing one; altruism is a growing force. We feel that we are called upon to counteract the evils arising from the growth of our cities; from the concentration of workers in large bodies; from the minute subdivision of labour; from the depressing conditions under which the masses daily toil. To provide relief and healthy occupation for leisure hours, to secure that vacuity of mind and pettiness of motive shall no longer be the sore affliction they now are, we must take all the requirements into consideration and define with utmost minuteness the task in hand; broader and higher ideals than those now prevailing must be established, practical requirements must be met. To secure the right attitude of mind for this task will not be easy. Few realise, few know, how signal is our failure to appreciate our power, how deplorably we neglect our opportunities. The bareness of the fare we provide is nothing less than shameful in view of the rich possibilities which lie ready to hand. In saying that

> A primrose by a river's brim,
> A yellow primrose was to him
> And it was nothing more,

the poet has well pictured our average attitude towards our surroundings. To the majority indeed a primrose

is scarcely a primrose; it is unseen. It is little short of impossible to account for our callous disregard of the wondrous beauty of the multitudinous objects displayed in Nature's realm, our willingness to remain ignorant of the meaning of the mysterious changes which are ever happening before our eyes. That familiarity should breed such contempt is passing strange; but how great the guilt in these days of those who allow the contempt to grow up, knowing as they must that the ignorance is easy to dispel, knowing also that those versed in the mysteries have ever sought to lay bare all that is within their ken. The failure on the part of those who have the charge of education to make a scientific use of the imagination is nothing short of complete; there is nothing to show that the imagination is ever called into play.

Surely it were time to make some real effort to imbue all with a proper understanding of their surroundings, to create in all minds a higher and reverent interest in life.

It is a sad reflection and a grievous blot on our civilisation that our spiritual advisers are mostly so little regardful, so destitute of understanding, of the works of that Omnipotent Power which all must recognise and humbly submit to whether or no allegiance be acknowledged in doctrinal terms: they before all others should be prepared to consider their inmost meaning and to direct attention to their wondrous mechanism. We indeed need to send forth a new mission charged with the holy duty of enabling man to appreciate and acknowledge the beauty of the universe as well as of preparing him to be a thoroughly effective worker, thus fitting him for the true, unselfish and reverent enjoyment of life. To use the apt words

of the Master, quoted by the Poet at the Breakfast-table: "If for the Fall of man, science comes to substitute the Rise of man, it means the utter disintegration of all the spiritual pessimisms which have been like a spasm in the heart and a cramp in the intellect of men for so many centuries."

If we can but make sweet use of our present adversity, though we may not be exempt from public haunt but live even in crowded cities, we shall unquestionably soon find

> . . . tongues in trees, books in the babbling brooks,
> Sermons in stones, and *good in everything.*

The wonderful prescience of our great poet is nowhere more clearly displayed than in these lines; it is more than surprising that although generations have been charmed by the music of the words so little has been done to realise their meaning or to give them a meaning in the minds of the majority.

It is but a question of attitude, for as Carlyle somewhere says, "so soon as men get to discern the importance of a thing they do infallibly set about arranging it, facilitating it, forwarding it and rest not till in some approximate degree they have accomplished that."

Unfortunately, there are all too many things of which we fail, through our faulty education, to discern the importance but which a little understanding, the exercise of some slight imaginative power, would enable us to appreciate. I will take the word *Energy* as an example. No word in the English language carries more meaning to those versed in the principles of physical science: yet how narrow is its connotation in the minds of the uninstructed majority. As a guide

of practical conduct, no word is of greater significance; if its true implication fully seized us the word would ever rankle in our ears and serve to remind us of the maxim, "Waste not, want not." In Great Britain we are using up our coal stores at the rate of over two hundred millions of tons per annum. Used at such a rate, the supply cannot last many generations; whence will our children derive their supplies of energy? Energy cannot be created. When we have squandered the wealth funded on our earth by the sun in æons past, we must fall back on the modicum we can snatch from the daily allowance the glowing orb dispenses, for his largess will for the most part be wasted and will be very difficult to garner in our country: sun-mills, wind-mills and falling water being but irregular and ill-disciplined servants, trees growing but slowly. In all civilised countries the same criminal waste of fuel—of energy—is going on; but although we recognise that individual men have no right to live beyond their means and have little pity for bankrupts, no corresponding feeling exists on the subject of collective squandering. The spendthrift is regarded with equanimity, because he but distributes his gold among the many—so that the many gain while he alone is the loser—but the energy of fuel is spent irrecoverably and all waste is not merely apparent but real. To waste fuel is to court criminal bankruptcy; but to how many does it occur that we are all parties to such a crime? Does any schoolmaster or schoolmistress call attention to the fact? How many heads of schools could even write a respectable essay on such a topic? When I have suggested "A piece of coal" as the subject for a scholarship examination essay, I have actually been told by literary critics that you have no

right to ask for knowledge of facts in a schoolboy's essay, the object being but to find out to what extent he can "gas" in flowing periods! A scuttle full of coal excites no emotions in the literary mind; it should be one to call up harrowing visions, as well as a vista of memories extending far back into the ages of time—for in no other stone can we find a more wonderful sermon.

To descend to the ordinary level, how many householders ever take into consideration the wicked waste of fuel which goes on in their establishments? how many are really thrifty in the use of fuel? I never see a "Kitchener," or hear it roar, but I shudder. The prevention of smoke is of no consequence in comparison with the prevention of the waste of fuel. Even when every care is taken the waste is very great—simply because our means of utilising the energy of fuel are so imperfect. The best steam engine can recover for us but very few per cent of the energy stored up in the coal which is burnt in its boiler fire. If we could succeed in burning fuel electrically—in directly converting the latent energy into electricity—it is conceivable that the engine might be of nearly theoretical efficiency. But what imaginative power must be exercised to secure such a result! Cannot we in some measure hasten the time of such discovery? Professor Perry not long ago had the temerity to direct attention anew to the subject in *Nature* and made what many practical people will consider the impossible suggestion of a wildly imaginative, irresponsible Irishman: that a round million or so should be devoted to systematic experiments, with the object of discovering means of increasing the efficiency of our engines. If we consider what is the cost of a modern battleship; if we consider what has been spent on the war in South

Africa; if we consider the extent to which the value of the fuel at our disposal would be increased if we could only double the efficiency of our engines and of our stoves, Professor Perry's proposal cannot be regarded as otherwise than modest and sensible. But what is of real importance is the implied suggestion that the subject should be seriously inquired into at national expense. It must and at no distant date be admitted that our fuel stores are national assets over which there should be some national control.

I may take Food as another subject of which we fail to discern the importance and which is outside the schoolmaster's ken, although teachers have stomachs as well as other men and boys in particular are believed to take some interest in the existence of that organ. It is but a variant on that of energy, as the food we take is mainly of value as the source of the energy we expend—as fuel, comparatively little being required for the construction and repair of the bodily machinery.

> . . . God has made
> This world a strife of atoms and of spheres
> With every breath I sigh myself away
> And take my tribute from the wandering wind
> To fan the flame of life's consuming fire.
>
> OLIVER WENDELL HOLMES.

How many will appreciate this pregnant passage? In how many schools is instruction given which would make it possible to recognise its beauty and completeness as a statement of the philosophy of the respiratory process? Our ignorance of ourselves and of the functions of food is indeed phenomenal. Life involves the unceasing occurrence of a series of changes for the most part chemical. If the proper study of man be man—as the highest dignitary of our Church some

time ago asserted it was—the ordinary person would be prone to assume that those in charge of education would so direct studies as to give man some interest in his own wonderful mechanism; instead they almost uniformly direct that true 'culture' consists in knowing what he has thought and written of himself in classic tongues in ages gone by before the slightest vestige of understanding of the phenomena of life had been obtained. And we moderns calmly suffer this and at the same time wonder at the way in which primitive peoples allow their medicine men and wizards to dominate them. Taking into account what is known, ours perhaps is relatively a deeper savagery than is that of most untutored races: our educational priesthood are for the most part never trained to a knowledge of the mysteries and deny admission through ignorance rather than wilfully.

From food to the preparation of food is an easy step—in point of fact the knowledge how to prepare food properly is of far more importance than any knowledge of what food is and does, as on it depends much of the happiness and health of mankind. Cooking is a branch of applied chemistry. We live in a scientific age—an age of knowingness. We might therefore expect that our girls at least would be so trained at school that with little effort they could become knowing cooks. I am not aware that the authorities who lay down the regulations for University Locals or similar examinations have allowed any such vulgar considerations to guide them in drafting their examination schemes: niceties of grammatical construction, recondite problems in Geography and History, the views of an ancient philosopher who gave himself up to angle worship, are alone thought of on such

occasions; and yet there are times, it is said, when these august persons deign to take some notice of culinary efforts: they cannot be unaware that cookery is a subject of some importance, which might well at least be led up to at school. To justify my reference to the subject, let me read a passage from "An Address on Education," delivered, not by a narrow-minded Goth who is so lost to reason as to doubt the sufficiency of an exclusively literary training as a preparation for life, but by a classic, the Headmaster of a great public school, Thring of Uppingham, in speaking of the Higher Education of Women at St. Albans in 1886.

> We English are proud of our homes. We sing songs about them, we write on them; in fact, we are very justly *proud of our homes.* Has it ever entered your minds that home to the great majority in a very large degree, and to all in some degree, is but a loftier name for cookery? In a cottage good cookery means economy, luxury, health, comfort, love. . . . Cookery to the vast majority of mankind means home and when the weary worker comes back from work wanting to refit, cookery alone can turn him out fit for work again. From this point of view home is cookery.

Cookery is certainly a subject of which those in charge of education have not yet in any way discerned the importance. Our cooks are inferior and wasteful simply because they fail to exercise sufficient imaginative power. If we wish to make good cooks of our girls, we must teach them to think for themselves and to be imaginative—to make a scientific use of their imagination; they will then come to see that the subject is a vastly interesting one, full of opportunity for research. The kitchen, of all places, is the one, in fact, in which the heuristic method should most flourish.

Could we find tongues in trees we should doubtless

find them eloquent on the subject of food supply and far more delicate in their tastes than any mortals. But how many of us, looking at a green leaf, can in any way call to mind the wonderful mechanism which enables the plant to secure the main bulk of its solid substance from the fleeting stores in the circumambient atmosphere; or the manner in which it is dependent on light; or its mineral needs; or its great need of water and its wonderful transpiratory activity? And yet the chief industry of the world is agriculture—the feeding and tending of plants. At least those who lead a rural life should have their imagination excited on such subjects at school; it is even possible that much of the asserted dulness of a country life might pass away if an interest in plant activity were properly cultivated. And schoolmasters might even find comfort in the reflection that, as Messrs. Brown and Escombe have recently shown, the translocation of the material first formed in the leaves, metabolism and growth are become so intimately correlated that the perfect working of the entire plant is only possible in an atmosphere containing the normal amount of three parts of carbon dioxide per ten thousand; they might recognise in the plant an organism after their own heart, with ripened conservative instincts and unwilling to accept any other than the limited diet long favoured by the craft.

In these days not only the obvious but also the microscopic forms of life claim attention; it is imperative that all should be at least aware of their existence and mindful of the deadly power that some of them exercise. All should be able to read with intelligence the wonderful story of the beneficent labours of the great Pasteur—a true saviour of mankind—and

appreciate their value. The lessons of sanitary science will never be properly brought home to us and heeded in daily life until a more direct intimacy with micro-organisms is encouraged at school.

And whether or no there be "good in everything," children must at least be encouraged to seek it; to use their eyes always and to reflect on what they see. A proper use will be made of leisure and of holidays when they are so trained; even "Days in the Country" will then be days of enjoyment and peace for all—never of mere vacuous wanderings, let alone of wanton destruction—and will leave no memories of broken glass and waste paper behind them. And in the end, the national drink bill may be considerably diminished if Shakespeare's words come to have some slight meaning for all.

Let us consider what we can do to further this most desirable end. Section L is in advance of the times, being concerned with a non-existent science—the Science of Education. The science will come into existence only when a rational theory of education is developed and applied; but it is clearly on the very eve of coming into existence, otherwise the Section could not have been established; and we may contribute much to its development.

Surely, the primary article of our creed will be that—as Thring has said—"the whole human being is the teacher's care," for all must admit that the faculties generally should be cultivated and educated. At present we make the fundamental mistake of disregarding this truth but there is evidence that sounder views are beginning to prevail. It is very noteworthy, for example, that in the recent report of the Committee

on Military Education it is laid down that *five* subjects are to be regarded as *necessary* elements of a sound general education, viz., English, Mathematics, a Modern language, Latin and Experimental Science. Moreover it is recognised that each of these subjects has a peculiar educational value of its own. Such a conclusion takes the breath away; indeed, it is almost beyond belief that Headmasters of Public Schools could commit their brethren by attaching their names to a report containing such a paragraph as the following:—

> The fifth subject, which may be considered as an essential part of a sound general education, is Experimental Science, that is to say, the Science of Physics and Chemistry treated experimentally. As a means of mental training, and also veiwed as useful knowledge, this may be considered a necessary part of the intellectual equipment of every educated man, and especially so of the officer, whose profession in all its branches is daily becoming more and more dependent on Science.

Just consider what this recommendation means: that it is now publicly admitted by high authority that *all* boys should have the opportunity given to them at school of gaining knowledge *by experience*—by actually doing things themselves, not merely by reading about them or being told about them, because this and nothing short of this is what is aimed at by all who advocate the introduction of Experimental Science as a necessary part of school training. The reign of the cleric as absolute monarch of the school kingdom will be at an end if such doctrine be accepted and acted upon; there will be some chance of our regaining the reputation of being a practical people. Members of the British Association will be carried back in a dream, some thirty odd years, to 1867, when a report from a Committee, consisting of the General Officers of the

Association, the Trustees, the Rev. F. W. Farrar, the Rev. T. N. Hutchinson, Professor Huxley, Mr. Joseph Payne, Professor Tyndall and Mr. J. M. Wilson, specially appointed to consider the best method of extending Scientific Education in schools, was presented by the Council to the General Committee and it was resolved: "That the President of the Association be requested to communicate the Report to the President of the Privy Council," etc. One among the reasons then given why general education in schools ought to include some training in science was, "as providing the best discipline in observation and collection of facts, in the combination of inductive with deductive reasoning and in accuracy both of thought and language." History does not record what the Privy Council did with the memorial. Had the Council been mindful of its duty to the country and paid serious attention to so weighty a representation our present position might have been a very different one; the German and American bogies would have assumed less portentous dimensions in our eyes and we might have found ourselves far better prepared than we were to cope with the conditions in South Africa. Accuracy of thought and language, according to the evidence given before the Committee on Military Education, are qualities in which military candidates are particularly lacking, notwithstanding the asserted value of Latin—the chief subject of study in the Public Schools—as mental discipline.

Unless we are prepared to disregard not only all the lessons of the recent war but also the lessons we have been receiving during years past in the wider war of commercial competition; unless we are prepared to disregard the still wider consideration that education

must be an effective preparation for life and not merely for business: the findings of the Committee on Military Education must be embodied in our practice. Undoubtedly the real issue decided by the Committee was the question whether the *antecedent*, not the technical, training of military candidates was properly conducted. In other words, *our Public School system was on its trial.* Although not referred to in so many words, this system is most effectively condemned in spirit in every line of the Report and far more between the lines. But the Committee have merely recognised what has been known for years and years; not a single novel point is brought out—not a single novel issue is raised in their report. By making definite recommendations, however, they have lifted the subject on to a higher plane; and it is these recommendations which require the most careful consideration *and revision:* for if carried out as they stand there will be little improvement in our condition. The Committee have certainly done more than they were asked to do but not more than they were bound to do. By the terms of reference they were to consider and report what changes, if any, are desirable in the system of training candidates *for the Army* at the Public Schools. Instead they have recognised that education at secondary schools has in a great measure conformed to the course generally prescribed by public professional examinations originally designed to secure the selection of candidates who had availed themselves of the advantages of a good general education; and that the State has been careful in the matter of examinations that they should be so framed as not to disqualify or hinder the unsuccessful candidate from entrance into other professions: in other words, that neither more nor less is to be exacted from candidates

for entrance into the Army than from candidates for other professions. Consequently, the requirements to be laid down for Army candidates are such as can be met from a sound general education; they are in no way special. The Committee have, in fact, pronounced judgment on the subject of all others which is of greatest consequence to the nation at the moment. But they were not actually appointed for such a purpose, although they should have been, as it was to be foreseen that the major issue must be tried if the minor were to be settled. The modern spirit in education was not sufficiently represented on the Committee. Of the witnesses examined too few had any practical acquaintance with the work of education, although a great many who could judge of its effects gave evidence; and the practical side of education was scarcely considered. Only one witness was examined on behalf of "Science"; Mathematics was unrepresented. Such being the case, it is surprising that the Committee should have gone so far in their recommendations and a proof how overwhelming the case must be in favour of change.

Among the signs of the times showing that liberal views are coming into vogue, I may refer to the provision made in the new buildings designed by Mr. Aston Webb and Mr. Ingress Bell for Christ's Hospital School, which was removed from London in May last. The new home of this ancient foundation is situated in the county of Sussex, about four miles south-west of Horsham, and comprises an area of 1300 acres of land —meadow, arable and woodland. Nearly £600,000 has been expended on the new school up to date. Provision is made for 800 boys; together with the

necessary staff these will form a colony of some thousand persons. The school provides its own water supply, disposes of its sewage by the bacterial system on its own premises and is lit entirely by electricity generated on the spot. Only food and clothing are derived from the outside. If senior boys, in the future, are allowed to gain some insight into the interior management and economy of such an institution, what wonderful opportunities they will enjoy! And I hope the day is not far distant when boys will learn to understand everything connected with the school in which they pass so many years of their lives. A school should be the last to deny to boys every opportunity of gaining such invaluable experience. Fortunately Christ's Hospital School is conducted on the hostel system; the masters therefore are not charged with household cares and have no temptation to withdraw their thoughts from the work of education. The school has no taint of commercialism about it. It will be a happy day for our country when this is true of all our schools.

The school buildings are placed nearly in the centre of the site and cover an area of about eleven acres. They are disposed along a slightly convex line facing southwards, the extremities curving gently towards the east and west respectively. The main range has a frontage of 2200 feet. At the eastern end, detached from the main range and somewhat retired, are the Infirmary and Sanatorium, which have a frontage of 500 feet. There are extensive playing fields and also a Gymnasium and Swimming Bath.

The scholastic buildings are grouped in the centre around a "Quad," 300 feet by 240 feet.

The Dining Hall, 154 feet by 56 feet, behind

which are the Kitchens and subsidiary offices, is placed on the north side of the Quad. The Chapel has sole possession of the western side. The School Hall, 130 feet by 50 feet, is at the centre of the southern side, class rooms being provided in two buildings parallel to it but separated by intervals of 40 feet.

The Science School faces the Chapel, filling the eastern side. The Art School and Library are arranged at right angles to it, somewhat in the background. The Science School consists of four main "laboratories" with subsidiary smaller rooms attached to each. No lecture rooms are provided, as Science is to be studied at the work bench; but each of the laboratories has a space arranged so that demonstrations may be conducted within it. The laboratories are fitted up as workshops as well as in the ordinary way, so that boys may use tools as well as test-tubes; and the effort has been made to keep the fittings as simple as possible. Workshops for specific manual instruction will be provided in addition to the Science Schools. Experimental Science will be taught throughout the school. It will be obvious that body, mind and soul have all been cared for. Whilst due provision has been made for the intake of that energy which is so indispensable to the indulgence in mental effort as well as to the maintenance of the vital machinery, science has received recognition at the hands of the designers of the Buildings, of the Governing Body and of the Head Master in a manner heretofore unusual: it has actually been placed on an equality even with religious and with literary study and it may be hoped that the reverent regard of the beauties and wonders of Nature gained in the Science workshops as well as in the

surrounding country will but deepen the feelings of devotion proper to the Chapel and greatly help in lifting the life of the school to a high level. May the example not be without effect.

It has been my privilege to act as the nominee of the Royal Society of London on the Governing Body of the School during several years past and I may be permitted to bear witness to the manner in which one and all have been mindful of the needs of the times in arranging the new buildings. I believe few Governing Bodies of Schools will do otherwise than promote advance, if properly advised. Resistance to progress comes from within the schools. The public must force the schools to reform.

Let me now return to the recommendations of the Committee on Military Education. It is to be noted that they clearly involve the recognition of two sides to education—*a literary and a practical.* I use the term practical advisedly, because it would be wrong to draw a distinction between a literary and a scientific side, as the whole of education should be scientific and science—true knowledge—and scientific method—true method—should pervade and dominate the whole of our teaching, whatever the subject-matter; and as the object of introducing experimental science into the school is to give the scholars an opportunity of gaining their knowledge at first hand—by practical heuristic methods, as distinguished from literary didactic methods—the introduction of such discipline may be properly said to involve the recognition of a practical side.

The term practical must not be understood as the antithesis of theoretical. Practice is inseparable from theory in all true teaching, the advance from one

practical step to the next being always over a bridge of theory. But if it be granted that education necessarily has two sides, it follows that the Committee on Military Education are illogical in their recommendation that Latin and Experimental Science may be treated as alternative subjects: they are but complementary, not alternative, subjects. The only possible alternative to Latin would be a subject in the literary branch—another language, in fact.

But the recommendations of the Committee are also far from satisfactory on the subject of languages. "The study of languages," they say, "forms a third main feature of a sound general education. Of these the most important, from an educational point of view, is Latin. Modern languages, though much inferior to Latin as a means of mental discipline (at least as generally taught), must none the less be regarded as an important part of a sound general education." In face of this conclusion it would have been logical to make a modern language rather than Latin the alternative to experimental science: obviously the Committee dared not omit the modern language. It is true the recognition of experimental science and Latin as possible alternatives may be regarded as a high compliment to the latter but it was never intended to be such; in truth it marks the recognition of the inevitable: that Latin will ere long be deposed from its high estate and intellectual freedom granted to our schools, greatly to the advantage of Latin, I believe. There is no doubt that the relative value of Latin as an educational subject is grossly exaggerated; those who dwell on its merits are rarely conversant with other subjects to a sufficient extent to be able to appreciate the effects these would produce if equally

well taught. As a matter of fact, in the case of Latin the most capable teachers have been chosen to teach the most capable boys; the results obtained have been unfairly quoted in proof of the superior value of the subject. We have yet to discover the highest value of other subjects, their depth of power as disciplinary agents having been most imperfectly sounded. And if we consider results, do not they afford proof that the belief in Latin (as taught) is misplaced? It has been the staple subject of education and has been supposed to afford the most valuable training possible in composition.[1] Nevertheless the complaint is general—not only here but also in Germany where Latin is far more taught and believed in—that composition is the one subject of all others which the schools do not teach. The fact is, Latin is a subject which appeals to the minority of scholars; the time of the majority is wasted in studying it. I would give to all an opportunity of proving their aptitude in Latin and Greek or at least some opportunity of appreciating the construction of these languages; but I am inclined to favour the proposal —made by high authority, I believe—that such studies should follow that of modern languages rather than precede it. The true study of classical languages

[1] Dr. Warre was continually harping on this point in his questions to witnesses examined by the Committee. Thus (Q. 3124): "I want to put Geography and History into English, and your composition would be tested in that way. We think, for instance, that Composition is admirably taught by translation from Latin or Greek. (To the witness): Would you agree with that, that translation from another language is teaching English Composition?"

Again (Q. 3129): "When officers have talked to us of the uselessness of Greek and Latin, they have neglected the fact that Greek and Latin are the great instructors in English." *Witness* (the Rev. A. Robertson): "I quite concur in that."

should be reserved for the University. In any case, it is beyond question that a very large proportion of those who would make magnificent officers are incapable of learning Latin to advantage; such will in future enjoy the inestimable advantage of studying Experimental Science; but if those who take up Latin are in consequence to lose all opportunity of acquiring some power of reading the secrets of Nature and of thereby developing thought-power and mental alertness—and such must be the effect of the adoption of the recommendations of the Committee—they will prove to be of little value to the army in comparison with their colleagues whose eyes have been trained as well as their "intellect." In the course of the evidence given to the Committee, Dr. Warre expressed the view that Science would kill Latin eventually. Nothing could be more unfortunate; but the course adopted by the Committee is that most calculated to bring about such a result, as Latin is thereby put in competition with a subject which must ere long be regarded as a necessary subject of school instruction under all conditions. Latin should be made one of the optional subjects along with Greek.

In their scheme of marks for the examination, the Committee put Latin, French or German and Experimental Science on an equality by assigning 2000 marks to each; but English and Mathematics are rated at a higher value, each receiving 3000 marks. It would have been better to have assigned equal values to the several group-subjects regarded as essential to a sound general education. It should scarcely be necessary to put a premium on the proper study of a man's own language; the subject has naturally a great advantage over others. As to

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should be reserved for the University. In any case, it is beyond question that a very large proportion of those who would make magnificent officers are incapable of learning Latin to advantage; such will in future enjoy the inestimable advantage of studying Experimental Science; but if those who take up Latin are in consequence to lose all opportunity of acquiring some power of reading the secrets of Nature and of thereby developing thought-power and mental alertness—and such must be the effect of the adoption of the recommendations of the Committee—they will prove to be of little value to the army in comparison with their colleagues whose eyes have been trained as well as their "intellect." In the course of the evidence given to the Committee, Dr. Warre expressed the view that Science would kill Latin eventually. Nothing could be more unfortunate; but the course adopted by the Committee is that most calculated to bring about such a result, as Latin is thereby put in competition with a subject which must ere long be regarded as a necessary subject of school instruction under all conditions. Latin should be made one of the optional subjects along with Greek.

In their scheme of marks for the examination, the Committee put Latin, French or German and Experimental Science on an equality by assigning 2000 marks to each; but English and Mathematics are rated at a higher value, each receiving 3000 marks. It would have been better to have assigned equal values to the several group-subjects regarded as essential to a sound general education. It should scarcely be necessary to put a premium on the proper study of a man's own language; the subject has naturally a great advantage over others. As to

Mathematics, there is no doubt that this also is a subject of which the relative value as mental training has been greatly over-valued; moreover that the methods adopted in teaching it have been very faulty: consequently much time has been wasted and its true value has not been appreciated, as it has been made to appear unnecessarily difficult and forbidding. The evidence before the Committee against Mathematics being carried too far was very strong. Thus Captain Lee, in examining Major-General Sir C. Grove (speaking of the training at Woolwich), said (Q. 604): "There was an immense amount of pure mathematics and so forth, which one never has occasion to utilise afterwards, unless one becomes an Instructor of Cadets at Woolwich, where you teach them the same useless things you have learned yourself." This elicited from General Grove the reply: "Well, there is a strange tendency in Mathematics—I do not know why—that wherever you introduce them they encroach horribly. I am always struggling to cut down advanced mathematics." And more to the same effect. Again, Lieutenant-Colonel S. Moores, when asked whether he considered the syllabus for the entrance examinations at Woolwich and Sandhurst to be reasonable (Q. 2353), at once replied, "No, sir; Mathematics are, in my opinion, very much over-valued as a subject for Army examinations, excepting for the Royal Engineers."

After all, if reasonable standards were adopted both in Mathematics and Latin, these subjects would not create the difficulty they do in examinations at present by absorbing so much of the time in school that no proper attention can be given to subjects in reality at least of equal importance. It should be insisted that fundamentals be thoroughly taught by practical methods,

so that the knowledge acquired may be real and usable: it is astonishing how far students may be carried in Mathematics, how real and interesting the subject becomes to them, when they grasp the fact that it has a practical bearing.

While dealing with Mathematics, I cannot refrain from quoting a statement made by Captain Lee (Q. 4209) with regard to the relative values of this subject and of science to military men, as the opinion he expressed is of very general application. "I think it is quite true," said Captain Lee, "that a great number of Artillery officers do go through their service without using Science, but I think they feel that any science they know proves of much more practical use to them in their profession than the Mathematics they have learned. As far as I know, in the most scientific branch of the Artillery, the Garrison Artillery, there are practically no occasions where a knowledge of Mathematics is required beyond the Mathematics necessary to solve a simple formula, whereas the lack of knowledge of Electricity, Steam and Hydraulics is often a serious handicap to the officer." I will venture to enlarge on this. Assuming that Latin, Mathematics and Experimental Science were taught equally well, by equally sound methods; assuming that they proved to be of equal value as forms of mental training (though, of course, developing somewhat different faculties): the training gained through Experimental Science would be far the most valuable, because the recipients would be brought thereby most intimately into contact with the world and most fitted to help themselves by having their thought-power developed. Of course this is but an opinion, yet it is one, I venture to think, which many share with me; nevertheless I make no superior

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claim for the subject and ask only that it should rank equally with literary and mathematical training among the necessary subjects of education.

It still remains to consider the specific recommendations of the Committee with regard to Experimental Science, as these are most unsatisfactory. Nothing could be more satisfactory than the manner in which the subject is dealt with by the Committee in their general report, paragraph 20, already quoted (p. 54). But on turning to the scheme of the proposed examination (Appendix A), it appears that not one Experimental Science but two Experimental Sciences are contemplated, viz., Physics and Chemistry, either of which may be taken in preference to Latin and together with English, Mathematics and French or German. A most important issue is involved in this recommendation; it cannot be too strongly opposed.

It is very strange and proof how little we are accustomed to act consistently or to organise, that having found a good thing we rarely make use of it. In the early days of scientific teaching, the elementary parts of chemistry and physics were taught as one subject; but gradually, as the individual sciences developed, this healthy practice fell into abeyance. Then time brought its revenge: it was seen that a very one-sided creature was being trained up; that the subjects were in reality interdependent. Moreover, a revolt had been setting in against the formal stereotyped manner in which chemistry was being taught in the schools; this came to a head about 1887 and a better policy was inaugurated by the Reports presented to Section B of this Association in 1889 and 1890, which condemned "test-tubing" in favour of problem work and led to the introduction of the quantitative

exercises which are now generally admitted to be of the first importance. Although the scheme put forward by the Committee dealt primarily with chemistry, being the work of the Chemical Section, it yet had a physical basis: physical measurement, in fact, was its life blood; all the earlier exercises described in it were in essence physical exercises; moreover the importance of paying some attention to bio-chemical and bio-physical phenomena was not overlooked. As teachers have gained experience of the educational value of the heuristic methods advocated in the British Association scheme, they have been led to apply them more and more widely and the teaching of Elementary Science has in consequence been regarded with growing favour of late years; more and more has been done to give it the necessary breadth so as to constitute it an effective system of "Nature Study."

The University of London — not the reconstituted body of the present day but the much-abused examining body of the past—after careful inquiry, a few years ago, advisedly substituted the subject of General Elementary Science for the specific sciences previously prescribed for the Matriculation Examination: by so doing it took a forward step which has generally been admitted by those who can really appreciate the issue to be one of the most important possible from an educational point of view. But the syllabus was imperfectly drawn up — although it had many good points — and the examination was entrusted to men who, besides having little sympathy with the subject, had scant knowledge of school requirements and possibilities. Consequently, the examination was a failure, as every one foresaw it would be if conducted without proper consideration. The new University has taken the *most unwise* step of

reverting to single subjects. It has done far worse than this, however, in making "science" an alternative subject. Such a reversal of the policy so long pursued by its forerunner can only be described as a *National disaster*. I make this statement with utmost consideration and trust that the fact that it is so pronounced from the Chair of this Section may give increased force to my opinion.

It may be claimed that the action taken by the Committee on Military Education is in harmony with that approved of by the Senate of the University of London. The only comfort left open to us is that afforded by the proverb that two wrongs do not make a right. Let us hope that wiser councils will ere long prevail. The consequences of perseverance in so narrow a policy must be very serious. Consider the effect even from a limited professional point of view. It is widely felt that, owing to the growth of knowledge, it is necessary to specialise if we are to do effective work; but this does not mean that we should be uncultured. We know that the very contrary is the case; that there was never a time when general knowledge was of greater value than it is at the present day. Yet how little this is recognised. The physicist is already unable to understand the chemist. And although the biologist is attempting to unravel almost transcendental problems in chemistry, he has but the most rudimentary knowledge of the subject. What intellectual pigmies we shall be if we pursue so short-sighted a policy; how ineffective must be our treatment of borderland problems. How little right men of science will have to reproach those who have received only a classical and literary training with lack of general culture if we remain so narrow within our own domain. And from a general

point of view the outlook is still more serious. The object of introducing Experimental Science into schools is to give training in knowledge of the world: to cultivate appreciation of its beauties and mysteries. To do this involves resort in some measure to all the sciences. Chemistry and physics are put first merely because they are of fundamental importance, chemical and physical changes being at the root of all natural phenomena.

As to the value of "Science" to military men, it is easy to understand that they should have little conception what it may do for them: having never received proper training hitherto, they cannot have had the opportunity of testing its usefulness or of appreciating its merits. But making all allowances, it is difficult to understand an answer such as that given by Lieutenant-Colonel Murray (Q. 4806) to the Committee on Military Education, viz., that "Science is a narrowing study for the young mind, and we want to widen and open the mind as much as possible; let them learn their science afterwards" (that is after the entrance examination). The contention of the advocates of "Science" has always been that of all subjects it tends most to widen and open the mind. Why attention should be specially called to this answer by the Committee in their report is a riddle; I hope it was because they desired to show they could rise superior to the occasion. But the idea that science "can be learnt afterwards" is a very common one and one of the most pernicious abroad. Learning from books and teachers is a lazy and ineffective method of learning; the average scholar is corrupted at an early age by exclusive resort to such methods. Much of the mental inertness of the day

is acquired at school by over-indulgence in book study. But apart from this, early youth is the period when the mind is most alert and the desire to acquire and to experiment greatest; it is the time when the powers of observing and of reasoning can be most easily developed into fixed habits: in fact, if they are not then developed, it is only in exceptional cases that the omission can be rectified in after life. It is too cruel that Mr. Shenstone, the one witness on the subject heard by the Committee on Military Education, should have given expression to the ill-considered opinion that the beginning of the study of Science necessarily comes somewhat later than that of Latin. The statement shows how prone we are to draw false conclusions, how little we think before we speak. The study of Science begins when the infant opens its eyes; every step it takes when it toddles is an attempt to apply the methods of experimental science; some training in scientific method is given in well-conducted Kindergarten schools; but when school is entered, the curtain is suddenly drawn upon all such rational study: if it be the fate of the child to enter a Preparatory school prior to entering a Public school, he is at once referred back to the times of the Romans and Greeks, his teachers being oblivious of the real lesson to be learnt from the study of the scholastic methods of classical times—that the training given to the youth should be such as to fit him to do his work as a man. How can our officers, how can any of us, be otherwise than ill-prepared to do our duty in the world when we are so treated as youths?

Of course all such narrow views, all such narrow actions, as those I have referred to are but conse-

quences of the lack of imaginative power — of our failure to make any scientific use of our imagination. Surely it were time we recognised this: that we sought to do our duty towards our children. An Arnold who could introduce morality into school method, not merely into school manners, would be a precious gift to the world in these days. Steeped as we are in mediævalism, we need some cataclysm—some outburst of glowing sand and steam such as the world has recently witnessed in the islands of Martinique and St. Vincent—which would sweep away preconceived opinions and give clearness to the atmosphere. American industry is distinguished by the readiness with which manufacturers scrap their machinery and refit. Why cannot we agree to scrap our scholastic and academic ideals—if not our schools and schoolmasters—and refit on scientific lines? If we are to weld our Empire into a coherent whole and maintain it intact, we must do so. Unless we recognise prophets—if progress be allowed to depend on the multitude—we shall perish. And time presses; we cannot with safety much longer remain a "nation of amateurs." An appeal must ere long be made to the masses to enforce the provision of leaders; it must be urged upon the men that they see to it that their masters are educated: for however democratic we may be in our ideals, history teaches, in a manner which admits of no denial, that leaders are the salt of the earth; and in these days leaders need a deal of training to be effective.

Unfortunately, it too often happens that those placed in authority are the very last to attempt to march with the times. Bodies such as our Universities, the Education Department and the Civil

Service Commissioners might have been expected to lead the way, to keep the most watchful eye on all that was happening, to note and apply all improvements. The very contrary has been the case. As a rule, they have advanced only under severe pressure from outside, scarcely a change can be credited to their initiative. It does not seem to have occurred to them that an Intelligence Department would be a desirable appendage. All suffer from the fatal blot that discretion and authority are vested only in a few heads of departments; the younger and more active spirits have no opportunity granted them while their minds are plastic, full of courage and instinct with advance: so when the time comes that they can act they have lost the desire through inanition. This is the terrible disease from which all our public offices and many industries suffer. It is right to accord experience its proper value but it is wrong to put aside youthful energy and inventiveness. Our American cousins owe their advance largely to the recognition of these facts.

At bottom the spirit of commercialism is the cause of much of the contorted action we complain of. Neither Cambridge nor Oxford will take the step which has long been pressed upon them—and never more eloquently than by the Bishop of Hereford in his paper read before this Section last year—to make their entrance examination one which would be in accordance with our knowledge and the recognised needs of the times, one which would have the effect of leading schools generally to impart the rudiments of a sound general education. They cannot act together and are afraid to act singly, each fearing that it would prejudice its entry if it took a step in advance and in any way sought to influence the schools. The

Colleges vie with each other in securing the best scholars in the hope of scoring in the general competition. And the Schools have discovered that successes gained in examinations are the most effective means of advertising: they are therefore being turned more and more into establishments resembling those engaged in the manufacture of *pâté de foie gras*, in which the most crammable are tutored without the least consideration of the manner in which lifelong mental biliousness is engendered by the treatment. Parents, with strange perversity, worship the success achieved by Tom and Dick, Mary and Jane; and think they are doing their duty by their children in allowing them to be made use of—for private ends. The worst feature of the system is the narrow spirit of trades unionism which it has engendered, which leads to the worship for ever afterwards of those who have gained the prizes, instead of regarding them but as victors for the moment and requiring them at each step to give fresh proof of power. Nothing is more unwise than the way in which we overrate the pretensions of the "first class" man; we too often make a prig of him by so doing. Those who succeed in examinations are too frequently not those most fitted for the work of the world. A long experience has convinced me that the boys a few places down a class are, as a rule, the best material. Those at the top may have acquisitive power but more often than not they lack individuality and the power of exercising initiative. We must base our judgment in the future on evidence of training and of general conduct, not on isolated examinations. If any sincerity of purpose be left in us, if any sense of the value of true training—of what constitutes true training—can be rescued from the scholastic wreck on

which we find ourselves at present embarked, we must institute some form of leaving examination which will give the requisite freedom to the schools and every opportunity for the development of individuality but at the same time necessitate thoroughness of training and patient regard of every grade of intelligence; leaders will show themselves and will not need to be examined for. Examinations as commercial enterprises must suffer an enforced bankruptcy.

Racing studs must be regarded as luxuries in schools and kept apart from the ordinary stables, these being regarded as the first charge upon the establishment, as the serious work of the world will fall upon their occupants. In other words, special provision must be made for scholars; they must not be allowed to monopolise attention and set the pace to the detriment of the majority. When Carlyle made the statement that we had in our islands a population of so many millions, mostly fools, he stated what is only half a truth. He failed to realise that the foolishness is very largely begotten of neglect and want of opportunity, not innate. Our schools mostly fail to find out the intelligence latent in the great majority of their pupils and give it little chance of developing by offering them a varied diet from which to select. During a long experience as a teacher, I have over and over again seen weaklings develop in course of time to strong men when they have been properly encouraged and an opportunity at last found for the exercise of their "talents." The Briton is in this respect a most mysterious creature: you never know when it is safe to call him a fool. All are agreed that the mistakes in the recent war were not due to lack of intelligence but to lack of training.

There can be no doubt of that. All who have taught in our colleges will, I am sure, agree with me that the material sent up from the schools is in substance magnificent but too often hopelessly unfit to benefit from higher teaching. The things said of those who enter for the military profession are as nothing in comparison with what could be said of those who enter for the professions generally. If our young people fail to show intelligence in later life, it is as a rule because the conditions under which we place them in earlier life are not only such as to leave their intelligence undeveloped but—what is far worse—such as to mar their ability. The best return we can make to those who did such magnificent service in the late war will be to take to heart the real lessons taught by the mistakes: to see to it that their children and their successors generally are trained in a happier school than that in which they were placed.

Examining bodies at the present time do not appear to realise the full measure of their responsibility. To examine well is at all times a difficult task, far more difficult than to teach well. The examiner wields a large measure of authority and it is imperative that he should exercise this wisely. Examiners should therefore be chosen with extreme care and with due regard to their fitness for the work; but this too rarely happens: the choice falls too frequently on specialists with little knowledge of educational requirements and possibilities. The examination of boys and girls is far too often put into the hands of those who have no real knowledge of the species and little sympathy with its ways.

There are three courses open to examining bodies:—to lead, to maintain themselves just abreast of the

times, to stagnate. As a matter of fact, the last is that almost invariably chosen — a syllabus, when once adopted, remaining in force year after year. Consequently, examinations tend to retard rather than to favour the introduction of improved methods of teaching. It is impossible to justify a policy which has such results. The evil effect of examinations would be less if the syllabus were abolished and the limits of examinations very broadly indicated; this is done in some cases and might be in all. The incompetent examiner and teacher are not in the least helped by the conventional curt syllabus but the liberty of action of the competent examiner and teacher and their desire to effect improvements are materially limited by it. The competent examiner should know what is a fair demand to make of a particular class of students and should be in a position to take count of the advances that are being made; the competent teacher should be able to do all in his power to make the teaching effective and be secure in feeling that his efforts could not fail to be appreciated. To take my own subject, the chemistry syllabus recently laid down for the London Matriculation examination is quite unsuited to its purpose and most hopelessly behind the times. The scheme put forward in the report of the Committee on Military Education is but a bag of dry bones. In the case of several subjects, the South Kensington schemes are full of the gravest faults, their hoary antiquity being their least objectionable feature. Surely a national institution, dispensing public funds, should be the last to hold back the nation; it should be provided with machinery which would enable it to march with the times. In making this criticism, I should like to recognise the great work done by Sir William

Abney in instituting reforms; but one swallow does not make a summer: a self-acting governing mechanism is needed which would at all times maintain the balance of practice with progress.

If we consider the process by which decisions on such matters are arrived at, even in the bodies representative of very large interests, it is a curiously imperfect one. Usually very few individuals are concerned. We are all still imbued with primitive instincts. In some way two parties arise and the question is, which shall conquer? More often than not the true inwardness of the issue presented is left out of account—the considered opinion of the day is scarcely asked for or if opinions are collected they are not weighed. Therefore, calm reason is rarely the arbiter. The conditions of modern civilisation require that some better method shall be devised which will really enable us to do that which would be of the greatest good to the greatest number. We do not sufficiently remember that while we are tilting, the enemy at our gates is contemplating our failure to maintain and strengthen our fortifications and quietly advancing his forces to the attack. Speaking of the Navy in the House of Commons not long ago, Mr. Arnold Forster said: "There was a need for some reinforcement of the intellectual equipment which directed, or ought to direct, the enormous forces of our Empire." Surely we may take these words as true generally.

At the present time, when the responsibility of controlling all grades of education is about to be cast upon the community and the actual call to arms is imminent, it is imperative that a sound public policy should be framed and that nothing should be allowed to stand in the way of the public good. It cannot be denied that

School Boards have done most admirable service; but there are many who are convinced that in not a few respects they have been disastrous failures: that we need a wider organisation, penetrated with sounder and especially with more practical views. The one essential condition of success is that the public should treat the matter seriously, realising that their own immediate interests are at stake; that they will be the first to suffer if those who are chosen by them to formulate the new policy and to supervise the work of education are unqualified and, let me add, to emphasise my meaning, unpractical. If the State is to retain any measure of authority, it too must be prepared to exercise that authority wisely. The blame to be put upon School Boards in England for having allowed an unpractical system of education in the schools is as nothing compared with the blame to be put upon the Education Department for having allowed such a system to grow up by the adoption of academic ideals and academic machinery. Until recently, it was a disqualification for an inspector to have teaching experience. A good degree, if not political influence, was the one qualification. Consequently men were chosen whose practical instincts had never been developed, who knew nothing of practical life and of common-place requirements, nothing of children and their ways; with rare exceptions the inspectors could look at education only from between literary blinkers. To intensify the evil the wicked system of payment by results was introduced. An inspector such as I have described, working under such a system, could not do otherwise than destroy teaching.[1]

[1] The inspector destroys teaching, because he is bound by law and necessity to examine according to a given pattern; and the perfection of teaching is that it does not work by a given pattern (Thring).

The first necessary step to take will be to reorganise the Education Department, root and branch; to imbue it throughout with sound ideals and lead it to understand its great importance as the head centre of the Educational system: for disestablish as we may and however much we may favour local self-government, a head centre there must be to correlate the efforts made throughout the country and to distribute wisdom; but its functions will be those of an exchange and enquiry office rather than directive and assertive. At least, such is my reading of the tendency of the *Zeitgeist*. Such a department will have an Intelligence Board, whose members are partly official, partly unofficial, so that it may maintain itself in constant touch with outside opinion and effort. One function of this Board will be to preside at a monthly bonfire of red tape and official forms; for in future, even if no other subject of Government concern be kept in a lively and living state, education must infallibly be. The whole staff of the office, including the inspectorate, will be required to avail itself of that most valuable institution, the sabbatical year, *i.e.*, to spend every seventh year in some other employment, so that they may not forget that the world has ways sometimes different from those pictured within the office which it is advisable to take note of in education. Refreshed and invigorated, they will return to work, prepared to sacrifice all sorts of traditions and to recognise the existence of short cuts across fields which had before appeared to be of interminable dimensions; and as it will be required that they spend a certain proportion of their close time in the company of children—if they have none of their own—they will learn that a child has ways and views of its own, none the less

interesting and worthy of consideration because they are somewhat different from those of grown-up people.

It is fortunate that the Technical Education Movement has been coincident in England with the development of the School Board system. Those engaged in it have worked untramelled by official requirements and much original thought has been enlisted in its service. In essence it has always been a revolt against the academic ideals permeating University education and the schools generally; the faults of the schools, in fact, are the more obvious in the light of experience gained in technical education, which will now come to our aid in correcting them.

The really serious tasks before those who direct the work of education in the immediate future will be the choice of a programme and the provision of capable teachers. If they enter on these tasks with a light heart, God help our nation; they will thereby give proof that they have no true conception of the great responsibility attaching to the position they occupy. Let no man offer himself for the work unless he feel certain that he is in some degree qualified.

As to the programme, it may be said that that is for the teachers to settle; and so it should be. But it cannot be denied that by long-continued neglect to read the writing on the wall, they have lost the claim to legislate; they have shown that they do not know how to legislate. The public must lay down the programme in its broad outlines; teachers must fill in the details. The task imposed upon the schools will be to develop the faculties generally—not in the lop-sided manner customary heretofore—and especially to develop thought-power in all its forms and the due application of thought-power.

I believe that gradually a complete revolution must take place in school procedure; that the school building of the future will be altogether different from the conventional building of to-day, which is but an expansion of the monkish cell and the cloister. Instead of being a place fitted only for the rearing of what I have elsewhere termed desk-ridden emasculates, the school will be for the most part modelled on the workshop, giving to this term the most varied meaning possible; a great part of the time will be spent at the work bench, tool in hand. Nature's workshop will, of course, be constantly utilised; and the necessary provision will be made for outdoor exercise and physical training. Scientific method will underlie the whole of education.

It will be recognised that education has two sides, a literary and a practical: that the mind can work through fingers—in fact, through all the senses; that it is not embodied only in the so-called intellect, a narrow creation of the schools. The practical training will therefore be regarded as at least equal in importance to the literary. Heads of schools will not only be potential bishops: almost all careers will be open to them. In fact, I trust the system will be in operation which I have already advocated should be applied to the Education Department: that the members of the school staff will be forced out into the world at stated intervals, so that they may not degenerate into pedants capable only of applying set rules much after the manner of that delightful creation Beckmesser in Wagner's opera "Die Meistersinger."

The class system will be largely abandoned. Children's school time will not be chopped up into regulated periods in a manner which finds no analogy in the work-a-day world: instead they will have certain

tasks confided to them to do and will be allowed considerable latitude in carrying them to completion. In fact, they will be treated as rational beings; their individuality and self-respect will be developed from the outset. The Boer War will have taught us to adopt open order teaching as well as open order firing. Schools will glory in turning out individuals instead of machines. The success of the Americans is largely due to the way in which Republican doctrines are applied to the up-bringing of children in America. We must follow their example and set our children free and encourage them to be free at an early age. The human animal develops at a sufficiently slow rate in all conscience; there is little need for man to retard his own development. School, with its checks upon freedom and individuality, should be quitted at seventeen at latest, I believe; all subsequent systematic training should take place at college. Boys are kept at school after seventeen mainly for the purposes of the school. It is claimed that by remaining they gain most valuable experience by acting as monitors and prefects; but this experience is enjoyed only by the few and might be obtained at an earlier age. Then it is said that seventeen is too early an age to enter Oxford or Cambridge; but this has only been the case since schools have retained boys to prepare them for examinations and in order that they might assist in the management. I believe that the attempts which have been made in these latter days to do college work at schools and to establish engineering sides in order to find work for senior boys have had a most detrimental effect. It is said that the training given in technical schools is too far removed from practice; but how much more must this be true of technical work done

under school conditions? The excessive devotion to literary methods favoured by schools and the older Universities tends to develop unpractical habits which unfit many to face the rough-and-tumble life of the world and is productive of a disinclination for practical avocations. By leaving school at a properly early period this danger is somewhat lessened; moreover it is necessary in many walks of life that school should be left early in order that the school of practice may be entered sufficiently soon to secure the indispensable manual dexterity and habits. For a long time past we have been drifting away from the practical; those who are acquainted with the work of the schools, especially the elementary schools, are aghast at the influence they are exercising in hindering the development of practical ability. We must in some way counteract this tendency. On the other hand, we have to meet the views of those who very properly urge that it is cruel to withdraw children from school even at the age we do. The two views must in some way be reconciled. The only way will be to so improve the teaching in schools that school becomes a palace of delight and the continuation school a necessity. The habits formed at school should be such that study would never be intermitted on leaving school. At present, school so nauseates the majority that on quitting it they have neither desire nor aptitude to study left in them: the work done in it is so impossible to translate into ordinary practice, so foreign to outside requirements.

The problem can only be solved by the scientific use of the imagination. The solution I would venture to offer is that an honest attempt be made to teach not only the three R's but also a fourth, Reasoning—

the use of thought-power—and that a properly wide meaning be given to all the R's.

Of all powers which can be acquired at school, that of reading is of first importance. Let teachers read what Carlyle says in the "Hero as Man of Letters," correcting his exaggerations by reading into his words some of the lessons taught by experimental science. Reading is not taught in schools in these days; if it were, people would not waste their time on the rubbish which now figures as literature, for which a rational substitute *must be found.* A well-read man is worshipped at the Universities and is held up to all comers as a pattern. Why should not children be encouraged to be "well read"? Let us admit this and sow books in their path. Thring, in giving utterance to his "Practical Thoughts on Education after Thirty Years' Work," speaks strongly on this point. "Great interest will make up for want of time. Create great interest," he says. These are noteworthy words. "As soon as children can read throw away all lesson-books for a time. Let them read. Let them read aloud—really read, not tumble through the pages. Give them to read poetry, the lives of good men, narratives of noble deeds, historical stories and historical novels, books of travel and all the fascinating literature of discovery and adventure. The person who has once learnt to read well is tempted to go on. And such books, selected by a carefully graduated scheme, would supply endless knowledge whilst kindling the mind, without any waste of time from drudgery and disgust. Geography, history and power of speech are all comprised in such books if properly used."

Thring here advocates what I would advocate—the *incidental* method of teaching. Why should there be

any set lesson in subjects such as history and geography? Nothing is worse, more stereotyped, more cramping to the intellect, than the set lesson of so many lines or pages, of a sort of Liebig's Essence of information, with the attendant obligation of committing the facts recorded in them to memory. The child, like the restive, high-mettled young steed, wants to be off and away—not to be held severely in hand. Why should not the method by which we get up a subject in later life be followed in schools? At least it should be properly tried. Let us give freedom to children and at least during early years lead them to read hard and wisely: they will do so gladly; and give them pictures innumerable in illustration of their reading. And children must not only be taught to read books: they must learn also to regard and use them as sources of information; the habit of flying for information to books must be cultivated. They must be constantly referred to dictionaries and works of reference generally; they must be set to hunt up all sorts of stories. Of course the scholastic Beckmesser will object that such a system is impossible, that there would be an end to all discipline; but to say this is to show a want of understanding of children and of faith in them and is proof of failure to recognise their power of accepting responsibility when it is properly put upon them. The secret of success lies in beginning sufficiently early; once let them appreciate what they are doing and the majority will work eagerly and spontaneously.

But when the full meaning is given to the first of the R's, it will be held to cover not only the reading of printed or written character but also the reading of some of Nature's signs, to the end that sermons *may be* discovered in stones and good in everything. That is

to say, at the same time that they are acquiring the true art of reading, they must be learning the true art of experimenting — to find out things by putting questions of their own and obtaining direct answers. The teaching of the elements of experimental science must therefore accompany the teaching of reading. And great care must be exercised that the palate for experimenting, for results, is not spoilt by reading. The use of text-books must be most carefully avoided at this stage in order that that which should be elicited by experiment is not previously known and merely demonstrated—a most inferior method from any true educational point of view and of little value as a means of developing thought-power. I regard Huxley's "Physiography," for example, as a type of the book to be avoided until method has been fully mastered. The great difficulty in the way of teaching the art of reading arises from the comparative paucity of readable books for young people. Text-books are not readable; in fact, they tend to spoil reading; and the majority of books are written for grown-up people having considerable experience of the world. The mistake is too commonly made of expecting children to master "classics." On the other hand, we need not fear allowing advanced books to fall into the hands of children; they are the first to despise the namby-pamby stuff that is too frequently offered to them. A new literature must be created, if education is to be put on a sound basis; something beyond mere word painting is required. Books are wanted, written in a bright, attractive and simple style, full of accurate information, which would carry us over the world and give clear pictures of all that is to be seen as well as of the character and customs of its inhabitants; and

books are wanted which, in like manner, would carry us back in time and sketch the history of the peoples of the earth. The various branches of science all need their popular exponents; our books are for the most part too technical; whilst much has been done to advocate the introduction of "science" into general education, little has been done to make this possible. Unfortunately those who attempt to write readable books are too frequently not those who are possessed of sound knowledge: it is time that it were realised by those who could write well and accurately that there is a duty incumbent upon them; on the other hand, something should be done to stem the torrent of text-books which is now flooding the field of education with the destroying force of a deluge, making proper reading impossible.

The true use of books has yet to be found and admitted; we do not sufficiently recognise their value as stores of information and savers of brain waste. Why should long trains of facts be committed to memory but to be forgotten? It is impossible to believe that such a process is mental training; it must involve loss of energy and mental degradation. In future we must give the training at less cost and teach the art of going to books for minute details whenever they are wanted. Nearly every subject is taught in an eminently selfish manner at the present time, the expert declaring that the learner must become acquainted with all the main facts of the subject, instead of recognising that it is far more important to acquire knowledge of first principles together with the power of acquiring the knowledge of facts whenever these become necessary.

The second R may be held to cover not only mere

writing but also composition. Why is the art of composition taught so badly? Because it is impossible even for children to make bricks without straw: they have little to write about under ordinary school conditions. The subject is also one, I believe, which must be taught incidentally—at least during the earlier years—and chiefly in connection with the experimental work; in fact, to make this last the training it should be, an absolute record of all that is done must be properly written out while the work is being done, too. Many teachers, I know, shy at this. It is their business, they say, to teach "Science"; it is not their office to teach literary style; but they are wrong: they must inevitably accept the burden if they are to succeed in teaching "Science" at all. An experiment, like an act, "hath three branches"—to conceive, to do, to utilise: a clearly defined motive must underlie it; it must be properly executed; the result must be interpreted and applied. It is only when the motive is clearly written out that it is clearly understood—that the meaning or intention of the experiment is clearly grasped; and this is equally true of the result. Of course, it is necessary to proceed slowly and not to demand too much from beginners; but it is surprising how the power grows. Drawing, of course, must be included under the second R; but this also may with advantage be taught incidentally and only receive individual attention at a later stage, when those who show aptitude in the incidental work have been selected out for higher instruction.

The third R must be held to cover, not merely the simple rules of arithmetic and all that is necessary of formal mathematics but also measurement work. Mathematics claims to be an exact subject: therefore

it must be treated exactly and made the means of inculcating training in exactness; not on paper merely but in fact. Moreover, physical science reposes on a basis of exact measurement, so that the introduction of experimental work into schools involves the introduction of measurement work as a matter of course.

The fourth R—Reasoning—will necessarily be taught in connection with every subject of instruction, not specifically. It is introduced as marking the absolute need of developing thought-power; and, in point of fact, should be put before all others in importance.

Under such a system as I suggest the time of study would be spent in two ways—in reading and experimenting. But whatever we do let us be thorough; the danger lies in attempting too much, too many things. Each step must be taken slowly and warily and a secure position established before going further.

Ireland is fortunate at the present time in that far-reaching changes are being introduced into its educational system. A body of men are engaged in this work who are, I believe, in every way specially qualified to promote reforms and earnestly desirous of developing a sound policy. The Irish race have rich powers of imagination such as no other section of the nation possesses: it is only necessary that these powers be trained to considered and balanced action to make the Irish capable of deeds before which the splendid achievements of the past will appear as nothing. Of course the development of a true policy must come about slowly; we must not be too impatient of results but give every encouragement and all possible support to those engaged in the work. It is before all things necessary to remember that the school is a

preparation for life, not for the inspector's visit; in the future the inspector will act more as adviser and friend, let us hope, than as mentor.

Turning to my own subject, the programmes laid down for primary and intermediate schools appear to me to be well thought out and full of promise, the only fault that I might be inclined to find being that perhaps they are somewhat too ambitious. But very able men are directing the work who should be able to see that thoroughness is aimed at before all things. Nothing could be more gratifying than Mr. Heller's statement in the Report for 1900, "that the Irish teachers as a whole seem to possess a great natural taste and aptitude for science and the method of experimental inquiry." May they seek to set the example which is sorely needed to teachers in other parts of the Kingdom. I fear there has been a good deal of hand-to-mouth teaching in the past; to avoid this, the teacher should not only have a carefully drawn-up scheme of work but should keep a diary in which the work accomplished each week is carefully recorded. In this way the weaker teachers will check any tendency they may have to relax their efforts and inspectors will be in the position to understand at once what progress is being made. Education, unfortunately, is subject to booms as the money market is; just now the "Nature study" boom is on. We must be very careful not to let this carry us away; whatever is done must be by way of real Nature study and must have very simple beginnings. In most of the work that is being boomed, the presence of the eternal book is only too evident; such teaching must be worthless. Let the teachers remember that the great object in view is to acquire the art

of experimenting and observing with a clearly defined and logical purpose. If they once learn to experiment properly all else will follow. The inspectors must give constructive help to the work; they too must be students and labourers in the cause of progress, not mere commentators. And there will be a great opportunity for experts to assist who can be helpful to schools. Every school should be provided with a workshop, simply equipped with flat-topped tables, in which all the subjects which are taught practically can be taken. Elaborately fitted laboratories are not only unnecessary but undesirable; the work should be done under conditions such as obtain in ordinary life. A due proportion of the school time must be devoted to experimental studies: no difficulty will arise when it is seen that so much else is taught incidentally; and that this is the case must be carefully borne in mind in arranging the curriculum—otherwise there will be much overlapping and waste of time. Lastly, every effort must be made to keep down the size of the classes. I trust that in Ireland the girls will receive as much attention as the boys. Experimental teaching is of even greater value to them than to boys, as boys have more opportunities of doing work which is akin to it in the world. The work done by girls should of course bear directly on their domestic occupations.

If we are to improve our schools the teachers must be trained to teach properly—or rather, let me say, must be put in the right way to teach, because practice and experience alone can give proficiency. This is the most difficult of all the problems to be faced in providing for the future. It is the one of

all others to be thought out with the greatest care; in solving it the help of all who can help must be secured. No amount of didactic teaching will make teachers; the training must be practical. To graft on the ordinary training a course of lectures on the theory and practice of teaching plus a certain amount of practice in a school is not enough. How can we attempt to teach the theory and practice of teaching when we are agreed that we do not know how to teach most subjects? How can a master of method instruct us how to teach subjects of which he has only heard? It cannot be done; in point of fact, we are talking about the thing—beating about the bush—instead of treating the problem as one which can only be solved by experiment. To teach method, you must know your subject; one man cannot know many subjects. Of course, there are quite a number of good general rules to be learnt but the application of these must rest with the specialist; and the only proper way of giving training in method is to teach the subject in the way it seems desirable that it should be taught. The end result of training should be the development of a spirit of absolute humility—of the feeling that no task is so difficult as that of teaching properly, no career in which finality is more impossible to attain to, no career which offers greater opportunity for perpetual self-improvement. The effect of the narrow and unimaginative system in vogue to-day is to send forth a set of young persons who arrogantly consider that they are "trained"; if they would only think of the amount of preparation involved in training for athletic competitions or in training race-horses even, they would entertain more modest views and be aware that they have everything to learn when they

commence their work. The Beckmessers reign supreme in our training colleges of to-day; they must be got rid of and true modest experts introduced in their place. The test of efficiency must be a real one, not that of a mere final examination. The inspectors must see to it that the instruction is given always with a view to the fact that the students are to become teachers, which at present seems to be the last consideration borne in mind. Every effort must be made to secure a higher class of student for the training colleges; a fair secondary training *must be insisted on.* A narrow spirit of trades unionism pervades the primary school system at the present time; School Boards and managers of Pupil Teachers' Centres make no effort to secure the assistance of secondary teachers.

My receipt for a training college would be: Develop thought-power and individuality; develop imagination. Teach whatever will do this most effectively; let special subjects be studied in the way that may best be followed in teaching them subsequently.

It is to the lasting shame of our State organisation and of our School Boards that so little has been done to provide competent teachers.

The future rests with the Universities; but to save the nation the Universities must be practical; broader conceptions must prevail in them. A course of training which will give true culture must be insisted on. The Universities have recently shown a disposition—to use a vulgarism—to throw themselves at the heads of the military authorities and to make special provision for the training of military students. It is much more their office to train teachers. Why should not the example to hand in the engineering

school at Cambridge be followed? Why should not a special Tripos be established for teachers in training? I believe this to be the true solution of the problem.

The desire now manifest in several of our large towns to establish new Universities comes most opportunely; it should receive every possible encouragement from all who have the interests of our country at heart. I believe the objection to be altogether fanciful—the outcome of academic views. It is said that the value of the degrees will go down like that of Consols. But in what does the value of a degree consist? Simply and solely in the evidence it affords of training. We regard the Oxford and Cambridge degrees as of value because they are proof that their possessors have lived for some time under certain conditions which are recognised to be productive of good. The degrees of other Universities must soon come to be regarded as proof of sound and healthy training. It must become impossible to obtain degrees such as the University of London has been in the habit of awarding, which have been the result of mere garret-study; proof of training will be required of all candidates for degrees.

But I must now bring this Address to a conclusion. The only apology that I can offer for its length is that having had over thirty years' experience as a teacher and being profoundly impressed by the serious character of the outlook, the opportunity being given me, I felt that "the time has come," as the walrus said to the carpenter,

> To talk of many things:
> Of shoes—and ships—and sealing-wax—
> Of cabbages—and kings—

And why the sea is boiling hot—
And whether pigs have wings.
("Alice through the Looking-glass.")

This list of subjects is no more varied and disconnected—the problems set no deeper—than those to which we must give our attention in dealing with education; and the sooner the fate of the oysters is that of our present educational "system" the better. Having shown by this quotation that I am not an absolute modern but have some knowledge of the classics, let me finally say, in the words of another poet—of him who on various occasions gave utterance to much wisdom at the breakfast table, that "I don't want you to believe anything I say, I only want you to try to see what makes me believe it."

Something more than an apology for an Education Act such as the powers are now engaged in shaping for us must be framed at no distant date and a determinate policy arrived at. That policy may perhaps be found in the words put into Hamlet's mouth:—

Hamlet. To what base uses we may return, Horatio! Why may not imagination trace the noble dust of Alexander, till he find it stopping a bung-hole?

Horatio. 'Twere to consider too curiously, to consider so.

Hamlet. No, faith, not a jot; but to follow him thither with modesty enough and likelihood to lead it, as thus: Alexander died, Alexander was buried, Alexander returneth into dust; the dust is earth; of earth we make loam; and why of that loam, whereto he was converted, might they not stop a beer barrel?

Imperious Cæsar, dead and turned to clay,
Might stop a hole to keep the wind away;
O, that that earth, which kept the world in awe,
Should patch a wall to expel the winter's flaw!

Shakespeare thus taught the use of the imagination before Tyndall! The fact that we can now carry our

imagination far further afield and contemplate the survival of atoms once embodied in imperious Cæsar in the flowers and fruit which deck the fair face of Nature—a higher end than that Hamlet paints—may serve to justify the adoption of a method he advocated. Modern progress is based on research—the application of imagination. Surely then there is every reason to make the spirit of research the dominant force in education!

V

THE NEED OF GENERAL CULTURE AT OXFORD AND CAMBRIDGE

In any discussion of the educational outlook, it is necessary to refer, in the first place, to the use which is made of the phrase "Technical Education," as it occurs so commonly. The term is of modern origin as a popular expression and of late years it has served more or less the purpose of a war-cry, having been much used as a means of rousing the dormant interest of the British public in higher education and in gaining funds for new educational enterprises. But it has also been the cloak under which instruction, in no true sense technical, has been given in the elementary principles of science, schools which would never have introduced such work, if left to their own devices, having been led to undertake it by the offer of grants in aid—a sufficient indication how little the curriculum of our English schools is determined by reasoned convictions or in accordance with a settled policy. The authoritative definition of the term which is given in the Technical Instruction Act of 1889 is so wide that under it instruction of any grade and in almost any subject, except Greek and Latin, may figure as Technical Instruction and be supported by State aid.

And obviously any form of specialised instruction tending to confer professional proficiency on the learner is properly spoken of as Technical Instruction; as a rule, however, the term has a more restricted connotation, being used specifically with reference to the education of those who are to engage in industrial pursuits.

The apostles of "culture" have always been scoffers at Technical Education. It is their wont to regard it as a narrow form of training in which there is a tendency to neglect what they are pleased to consider the intellectual requirements, *par excellence*, having themselves never had occasion to exercise "practical activities." But when, in days to come, the work of the pioneers of the Technical Education movement is more appreciated than it has been as yet, it will probably be admitted that their action has been based on an interpretation of educational needs far wider and more generous than that which underlies the older system of training. The humanists will then stand convicted of irreverent neglect of Nature and will no longer venture to imply that they alone are cultured. The Technical Education movement is, in fact, but the expression of the irrepressible tendency of the Englishman to be practical and the outcome of the desire that the faculties should be cultivated more fully and broadly than has been found to be possible under the system previously in vogue. As education spreads, academic ideals are seen to be both narrow and unnatural. It has been realised that it is not only unnecessary but positively undesirable to force all into one mould—to attempt to train all in one way; and that students are far more likely to work earnestly and derive full benefit from their studies when the subject-matter is chosen with some reference to their surroundings and

aptitudes and as far as possible with regard to their intended work in life; in other words, when it is put on a technical basis.

The Technical Education movement received a great, if not its chief, impetus from the inquiry set on foot by a committee of the Livery Companies of London in 1877, which culminated in the establishment of the City and Guilds of London Institute for the Advancement of Technical Education. The Finsbury Technical College—the forerunner in London of the now numerous Polytechnics—was opened by this Corporation in 1883; in the following year it established the Engineering College at South Kensington now known as the Central Technical College; it also at that time began to develop the System of Technological Examinations which have since led to the establishment all over the country of evening classes, more or less on the lines of the science and art classes which have long been subsidised by Government. But it was by the sudden and wholly unexpected grant of a large measure of State support under the Local Taxation (Customs and Excise) Act of 1890 that Technical Education became, at least in name, a subject of national concern. Complaint has often been made of the trivial character of much of the work done under this Act and of the money being wasted in consequence. There is little doubt that there is some justification for this charge; yet, on the other hand, the Act has been the means, all over the country, of inducing men who had not previously given any attention to educational work to take a real interest in it; and numerous experiments have been set on foot which have furnished most valuable experience. The country has been educating itself, in fact, to understand and undertake a new duty, perhaps in a somewhat

blundering fashion and with little forethought, each district striving to work out its own salvation and caring little to seek advice. But the result has been to create an interest which could not well have arisen otherwise; and possibly more real depth of feeling and a more healthy spirit of discontent are being bred among us in this way than are to be found in the countries counted more advanced than our own. Nevertheless, the numbers affected are very small, the work having been done by an intelligent but numerically weak minority and Philistinism is still rampant among the public at large.

Concurrently with the movement in favour of Technical Education, there has been a movement in favour of the extension of what is commonly termed University Education. Nothing, in fact, is more remarkable than the rapidity with which, during the past two or three decades, colleges of the University type have been established in various towns. The further step which is now being taken of conferring the rank of Universities on some of these colleges is but the logical outcome of a movement which has gradually been gaining strength almost unperceived; and apparently the meaning and force of this movement are still far from being recognised. In fact, we are accustomed to be accounted a backward people in matters of education. But bearing in mind the activity which has prevailed, it is at least open to question whether we may not be doing ourselves an injustice by failing to appreciate the extent of our performances—whether we may not be greatly underestimating the solidity of the foundation we are laying and, indeed, have laid. Whatever comfort we may be willing to find in such reflections, however, the fact

remains that we are to a dangerous extent behind the times in the development of an educational policy.

"All nations are learning that their commercial and industrial prosperity in the future depends on their methods of educating the whole nation"—such are the opening words of the Report to the Board of Education on Technical and Commercial Education in East Prussia, Poland, Galicia, Silesia and Bohemia, by Mr. James Baker—whom Mr. Sadler describes as a skilled observer of social developments—presented to both Houses of Parliament in 1900. We are learning this but learning it far too slowly. Even at the present time, when the organisation of a national system of education is before the public, questions of method, aim and object—the real crux of the problem—find no place in the discussion. Few among us see that we have allowed the work of education to remain too long in the hands of a privileged class, without inquiring in any proper manner into the way in which they have exercised their stewardship—into their competency to understand the situation, in fact. No attempt is being made to treat the problem in a scientific manner. Probably it is because education is controlled by people who for the most part do not understand the business that we are so terribly behind. Germany, at all events, has not adopted such a policy.

Without doubt the main cause of our slow advance is public indifference, which culminates in the manifest incapability of our rulers to understand the gravity of our position and to take action accordingly. But whence does this arise? Is it from innate peculiarities? or is our indifference an acquired habit? and whether innate or acquired, can

the habit be changed, so that our attitude may be one more consonant with the times?

"Many thoughtful persons fear that brave and enterprising as we are, and capable indeed as we are of throwing up very great men now and then, yet there is a core of stupidity in the corporate English character which keeps us dull to the value of wide and accurate knowledge, and of the functions of the organs of education and research." These words were used by the writer of a letter on Oxford and Cambridge Universities in the *Times* of May 24. That we are at heart a conservative and unimaginative people there can be no doubt; but it is difficult to believe, in view of our achievements, that there is any core of stupidity in our corporate character which keeps us dull. Rather is it probable that we wear the cloak of stupidity because it is forced upon us by convention and is now not only fashionable but in harmony with the environment. Fashions, we know, are set; they are not entirely the expression of innate qualities.

Whether fashion or not, our stupidity is manifest in our failure to recognise that a new spirit called scientific method has been breathed into the world. The majority do not see that much of the work of the world is now carried on under conditions as different from those which formerly prevailed as are the conditions under which battles are now fought between civilised nations from those under which primitive peoples fight. Yet a nation can only follow its leaders: if its leaders remain blind, there can be little advance. Our leaders still behave as though we lived in primitive times; our chief schools decline to consider what is going on in the world outside their

walls—to take notice of the new demands. And why is this the case?

The methods used in training an army date from the headquarters staff, although subalterns and non-commissioned officers do the actual work of teaching the units. In like manner, the methods used in training a people date from the headquarters staff—in our case from the ancient universities. It is they who are primarily responsible for our backward state—it is they who have failed to revise the national drill-books and, strange as the conclusion may seem, there can be little doubt that the main cause of their failure is that they have been too exclusively seats of advanced Technical Instruction—not places of true culture. They have been Technical Schools. They owe even their great success as schools of manners to the fact that they are advanced technical schools of the subject—in which, be it noted, manners are taught by example and not by precept. The studies to which chief importance has been attached are classics and the instruction in these has been of a highly specialised and technical character. In like manner, in our great public schools and in the preparatory schools from which they draw their supplies, literary subjects have almost monopolised attention and have been taught in such a manner that the instruction in them may be said to have been highly technical. Only the schools of lower grade, not dependent on the Universities, especially the so-called schools of science carried on under the ægis of the Science and Art Department, have made the attempt to devise courses of instruction of a broad and liberal character, such as would lead to the even development of the faculties generally and afford the equipment necessary to every good citizen. They

have not always been very successful perhaps, owing to lack of experience and the extreme difficulty of obtaining competent teachers as well as to the very imperfect character of the programme laid down for their guidance; but a beginning has been made and the existence of such schools, if only in an embryonic state, may be regarded as a healthy feature in a system otherwise sorely diseased.

Being rank specialists—classical scholars for the most part—the leaders of thought at the Universities have been unable to appreciate the changes wrought in the conditions of life by the development of the New Knowledge and by the application of the methods by which it has been brought into existence. They have continued to worship mere erudition; the art of experimental inquiry, which has enabled us to penetrate into the mysteries of the universe, has remained to them a sealed book. Naturally they have made no provision to secure better conditions for their successors. In fact, no attempt has been made by the ancient Universities to influence the schools and to secure cultured students by requiring that matriculants should prove that besides paying attention to literary subjects they had received some training in scientific method—some practical training. Moreover, the majority of graduates have been allowed to pass out after receiving treatment as one-sided and illiberal as that accorded to them at school. And in no case has the attempt been made to develop thought-power and mental alertness or to equip graduates with a full understanding of scientific method—to embue them with the spirit of discovery. The research work done in the Universities has been the result of post-graduate effort and not an integral part of the intellectual training they afford.

Too often those who have engaged in original studies have done so with their freedom of judgment most seriously impaired by a long course of dogmatic teaching. Every subject has been taught from the purely professional point of view—scarcely an attempt having been made to meet the special requirements of different classes of students; none to give general culture.

Our system of examinations and scholarships has tended in the same direction—to encourage cram and over-specialisation and to stifle the spirit of inquiry, the development of character. Indeed it is difficult not to believe that educational authorities have been engaged in a silent conspiracy to undo the nation and deprive the Briton of his chief characteristic—his individuality.

The need of an inquiry into our War Office administration and into the methods adopted in training our soldiers has been forcibly brought under notice by the course of events in South Africa. The recently published report on military education makes it clear, however, that not merely their military but also their antecedent training is in fault—and that a far larger issue than that of mere military training must be dealt with. In fact, we must provide against that wider war—the struggle for existence involved in commercial competition—in which the whole Nation, not merely its soldiers, is engaged and must continue to engage. If we can but submit ourselves to that rigid scrutiny which military affairs must receive now that the war is at an end and if in the fight against ignorance and prejudice we can but show the patience and determination which have characterised the war, we shall doubtless succeed in the end; but every day, every

minute, of delay, will vastly increase the cost and the difficulty.

If the Nation is to be led to appreciate the value of training, to understand what kind of training is necessary and to secure the necessary training, the Universities must reform in the first instance. It must be recognised that there is as great a need of reform in University ideals and methods as of reform in army ideals and methods; that, in fact, the greater covers the less, the army being but a part of the Nation. It may be objected that the Universities affect only the upper classes. But such is not the case; their influence ramifies throughout the nation and is daily increasing. They govern even the elementary schools, as those who train the teachers have been more or less directly trained by the Universities and the management of the schools is largely in the hands of university men. The Universities must become Universities in fact as well as in name: schools where both general culture and the highest form of technical instruction can be obtained; and where especially the view will prevail that the spirit of research must pervade all the teaching, so that at no distant date it may be recognised that no teacher can be efficient who does not see the constant need of advance and of perpetual wakefulness to opportunity.

The need of such a change is proved to demonstration by German experience. The Universities in Germany are places of national resort. Every well-educated young German awaits with impatience the day of going to the University—it marks his entry into life as a free agent, his escape from the narrow routine, the intolerable thraldom and merciless over-pressure of school. As often as not he enjoys a "good

time" at first and severely neglects his studies; but this is mere reaction. After an interval of much needed rest, he sets to work and works with stubborn tenacity of purpose. There are no tutors or college dons to keep him in order, no fellowships to be worked for, there is no competition for place—but there is an ever present example to develop his aspirations, as a considerable proportion of the senior undergraduates are engaged in research work. And in order to obtain permission to take the examination for the degree, he must submit a thesis of approved merit, embodying the results of some original inquiry he has been engaged in. Erudition is not aimed at and text-books take a subordinate place but the student is expected to show in the examination room that he is well acquainted with the literature of his subject. Strange and unnatural as it may seem to the English mind, the men who have taught him are assumed to know more about him than strangers from a distance would: having been trusted to teach him, they are trusted to examine him—and face to face, orally, not merely on paper.

The system has been in operation for a sufficent time to produce results—and very remarkable results too. It has led the public to understand what research work is and its value, as well as to attach a definite and real meaning to the term "Scientific"—perhaps not always a very broad one but yet a true one; and consequently it has brought Germany to the very front rank as a commercial and manufacturing nation. The methods of the laboratory have been carried into the works. No effort being spared to understand the inner meaning of every manufacturing process, a complete mastery and control of the operations is secured and economical administration ensured. Im-

provements are continually being effected. And most important of all, harmonious relations based on mutual understanding become possible between the departments, so that not merely the financial side but every detail of a manufacturing business receives full and proportionate consideration. King Rule of Thumb has fled before the German Universities—we still allow him to batten upon us.

No corresponding influence can be traced to our Universities. There is only one industry which prospers here under their direct patronage — the examination industry. It is significant that this meets with no encouragement in Germany and that the best opinion here regards its work as pernicious.

It cannot be too forcibly stated, however, that it is not the mere provision of educational facilities, nor even of an organised system, which has made the German Universities great and enabled them to be of such service to the nation. They owe their success to the spirit by which they have been actuated; to the fact that a high moral purpose has underlain their efforts; to the complete academic freedom which they have enjoyed. It is not what has been taught but the way in which the teaching has been conducted—especially the end in view—that has made the German schools and Universities effective. It will be of little use to increase the mere appliances, unless we can introduce a new spirit into our educational work—unless we can divest ourselves of clerical control and become practical.

But it is all important that we should not be led away by German success to suppose that German methods may be straight away adopted here: rather is it true that many lessons what not to do may be gained

from a careful examination of the present educational outlook in Germany. Even Mr. Sadler appears to see this, to judge from his article on "The Unrest in Secondary Education" in volume ix. of his Educational Reports. The real question is—may not Germany as well as England be engaged in spoiling its people? It is worth while to consider what Mr. Sadler has to say and to notice how even a man who by training belongs to the clerical party is being gradually led to see that there are practical issues at stake which cannot be disregarded. Mr. Sadler does not agree with the view expressed by a recent French writer that Prussia has encouraged all kinds of educational initiative. He recognises that the basis of Prussian secondary education is linguistic discipline—that, in fact, as he puts it, the whole system is adjusted to one general end: the high development of certain types of mental powers through varied processes of training predominantly literary in character. The system leaves very little liberty for the compensatory growth of quite other kinds of training. Yet, he says, it is often through these temporarily unfashionable or neglected kinds of training that new and much needed types of character are formed. And he recognises that there are signs that this immense machinery for more or less literary education tends to produce more than is wanted of a certain kind of aptitude and knowledge. It is refreshing to find so strong a believer as Mr. Sadler is in the efficiency of German methods beginning to see that there may be danger in accepting German ideals. The following passages from his article may be quoted as of special interest in this connection:—

Was there ever a time when the world needed more daring experiments in education, or when it was more undesirable that

one dominant kind of training should be taken as affording a sufficient touchstone for merit? We are in some danger of inducing a sort of intellectual nausea in many minds which would have responded to another kind of training. The German system of education, and those other systems of education which have been modelled on the German, seem calculated to produce what is organisable and imitative rather than what is creative and independent. Yet at a time like the present, which is a period not only of national and social consolidation on a vast scale, but also of new departures and of readjustment of aims and principles, both sets of qualities are necessary, and the habit of subordination without the gift of initiative may prove even more perilous in the long run than the gift of initiative unaccompanied by trained power of subordination. Should it not therefore be the chief aim of education to endeavour to produce that kind of independence which is never lacking in fresh initiative and in the power of taking fresh views of things, but is at the same time always conscious of the wisdom of the past and ever ready to subordinate its individual pleasure to any swiftly discerned occasion of public need?

Germany has devoted more thought and labour to the science and art of teaching than any other nation in the world. Throughout their system everything is considered. As little as possible is left to chance. They regard the questions how a subject should be taught, in what order it should be taught, how much time should be allowed for teaching it and what other subjects should be taught with it, as being of great consequence as well as of extreme difficulty. . . . They leave nothing to rule of thumb. They know how much depends on having first-rate machinery and on keeping it well adjusted. They think much more of what is going on inside their schools than we do. Educational interest is the real cause of their laborious study of methods. But the results of that study are not confined to the schools. A surprisingly large number of Germans possess the power of skilfully teaching other people the details of some practical business; and their pupils are as prepared to learn as their instructors are to teach. This is an educational aspect of German industry and commerce which is sometimes overlooked. In a nation of schools, nearly every department of activity becomes in a sense a school too. Those who possess the experience have cultivated the knack of impart-

ing it. They are not inarticulate and unable to teach their juniors what they themselves do so well. They have been trained to think about methods of teaching and to break up their knowledge in such a way as to impart the component parts of it in the order, form and measure best adapted to the mental preparation of the learner whom they desire to teach. In an educational atmosphere, school and workshop and office all co-operate in giving the learner an intelligent command of the principles and practice of his business.

The case for and against German educational methods is broadly and well brought out in these passages; but we need to go further and to penetrate more behind the scenes if we are to appreciate the real state of affairs; and we need to be far more careful in selecting our advisers than we have been of late. Statements such as many politicians indulge in at the present day may be very well as a means of exciting public discontent and therefore very desirable; but mentors of this class fail almost uniformly to observe a due sense of proportion; what they say is too often lacking in accuracy; and the advice they give is always very general and not of much value in the development of a practical policy. And even those who are called on to furnish official reports are often but ill qualified for the task: we are rarely mindful of the principle that if it be not best to set a thief to catch a thief, it is at least desirable to engage the services of a skilled detective. The author of the Report to the Board of Education on Technical Education in East Prussia, etc., for example, may well be, as Mr. Sadler says, a skilled observer of social developments; but the man who visits the Technical High School in Berlin has to study educational methods, not social developments. The report on the Berlin school published by Mr. Sadler is almost farcical in

many of its details; were it not typical of much that is being written for our instruction at the present day it would be unnecessary to refer to it. If we are to derive any real advantage from foreign experiences we must have the considered opinions of those who have been brought intimately into contact with the work on which they report. Above all, we need action, not reports.

Among those who know the country well and who knew it even before the last great war—having studied in its Universities and being aware of what is going on within its manufactories — not a few are inclined to think that Germany may be engaged in the process of killing the goose that lays the golden eggs: they would not only agree with Mr. Sadler in thinking that "the habit of subordination without the gift of initiative *may prove* more perilous in the long run than the gift of initiative unaccompanied by trained power of subordination"; they would go further and assert that such must be the case.

Individuality and originality are by no means characteristic of the German nation—rather is an infinite capacity for taking pains its dominant quality: any action which tends to depress individuality and originality must therefore sooner or later operate prejudicially. Now, of late years, in consequence of the complaints which have been made of the unfitness for technical posts of some of the men educated by the Universities, new educational schemes have been devised with the object of effecting improvements in the course of training. One result of the agitation is that the Technical High School system is gradually coming more and more into competition with the University system; and there is a strong tendency,

not only to increase the severity of the educational drill to which the student is subjected but also to change its character and render it less free. To understand this, it is necessary to consider the contrast afforded by the two systems. This is well expressed in the following opinion of an English student who has recently spent several years in Germany and who has endeavoured to appreciate their relative merits :—

> The main difference between High School and University is that in the former men are more taught, whilst in the latter learning is imparted more by sympathy—if one can so express the indescribable feeling of the gradual growing up of knowledge which comes to one in a German university, as contrasted with the system in which facts are hurled at a student to grasp or not as he pleases.

The Germans do not appear to have understood that the demands they have made of late years upon themselves have been excessive—that in consequence of the extraordinary prosperity of their industries the number of posts to be filled has been far larger than the number of men of real ability available, so that very second rate men have often been accepted: the failure of these latter has been too frequently attributed to faulty training instead of to innate incapacity. That the training given in the Universities might be improved there is little doubt; it is, however, questionable whether the direction in which improvement is sought for is the right one. But in a nation dominated by military discipline, the gradual expansion of a bureaucratic system scarcely excites comment; submission to orders gradually induces not merely the willingness but even the desire to be led. Such a system, moreover, provides no encouragement for the intervention of the public. In Germany there is much more

concentration of effort than is met with in England; in no other country is minute specialisation developed to so great an extent. And as a corollary, little interest is displayed either in questions of general educational policy or in the details of educational work, except by those whose profession it is to deal with matters of education. It is, therefore, not surprising that narrow ideals should prevail among the teachers. Their conservative attitude is well pictured in the interesting report in Mr. Sadler's volume, already referred to, by Mr. R. E. Hughes and Mr. W. A. Beanland, recording their impressions of some aspects of the work in primary and other schools in the Rhineland.

There is no doubt that if we look below the surface the forces at work here are fortunately very different from those which are operative abroad. Of late years, not only teachers in schools but also many of our professoriate have displayed the very greatest interest in educational work; indeed, the latter have been prime movers as reformers and have not merely criticised but have done their best to develop new and improved methods for use in elementary and secondary schools. They have realised that their work can never be properly done until the work of the schools below is properly done—until an organic connection is established between school and technical courses. The result is that whereas education tends to be stereotyped in Germany, it is here developing in an extraordinary variety of directions. Broader ideals are rapidly coming into favour; the desire is growing to make education practical and not exclusively literary as of old; and most important of all, purely didactic methods are falling more and more into discredit and

the attempt is being made to place the pupils as far as possible in the position of the discoverer, so as to give utmost development to thought-power and the spirit of self-helpfulness.

The Germans have made research work the mainstay of their Universities but it has never been introduced into their schools; we, however, are seeking to introduce it into our schools, in the expectation that it will then receive consideration from our Universities and be substituted for the soul-destroying didactic system of training at present in vogue. Professor Macgregor, the successor at the University of Edinburgh to the late Professor Tait, speaking of the importance of introducing research methods of study into the educational system and of Professor Tait's work in this direction, has given expression to this view in words that are worth quoting:—

> Tait's laboratory was an endeavour to counteract this baneful influence of the old system. He saw that mere book study in science was incomplete, that practice in measuring and in using of instruments did not suffice to complete it, that the only way to get out of science study the great educational benefit it was capable of affording was to study it by research, and that only thus could the study of science be made to exert its full influence, whether on the individual or on the national life. He doubtless saw that the wide employment of the text-book and the written examination in British schools and colleges must prevent the cultivation of resourcefulness and insight in science study, and that as the growing importance of science gave it a larger place in the curriculum, the continued use of the old method must more and more diminish the initiative of the British people. And so he encouraged his students to become investigators, and set them in his laboratory to find things out for themselves.
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> It is almost needless to point out how important it is that initiative should be cultivated throughout the long period that

is spent at school. It is vigorously cultivated during infancy by Nature, the wisest of teachers. It was largely cultivated in the old classical school, though on one kind of experience only. But in the modern school, and especially the modern side of the modern school, which, with a variety of subject suited to the complexity of our life, offers such facilities for its cultivation, it is almost wholly repressed by book study and the necessity of cramming for examinations. We need not be surprised, therefore, either at the prevalence of the opinion that the earlier young people enter upon their life-work the better, or at the conviction that is slowly dawning upon us that we are rapidly bcoming incapable of adapting ourselves to new conditions whether in conducting the operations of war or in prosecuting the arts of peace.

To sum up: Whatever elements of good we may discover in our educational work, it is impossible to deny that there is a total absence of organisation. The task before us is therefore a most difficult one. To secure success we must reform and organise our entire system—if the use of such a word be permissible where no system prevails; and we must reform at the same time both above and below. Unless a proper foundation be laid there can be no efficient higher or technical training; on the other hand, unless there be efficient higher training, the full staff required to give the preliminary and intermediate training cannot be forthcoming. And the establishment of an efficient system of technical instruction is dependent on the upgrowth of an efficient system of general instruction. Unless the Nation be willing to appreciate the value of technical knowledge and skill and to make use of it, the mere provision of opportunities of gaining such skill will avail us little. It pays Germans to spend much on their education because employers demand that their assistants shall be educated. It is because the German factories are

willing to employ large numbers of skilled chemists that it pays large numbers of young men in Germany to go to the expense of securing the necessary training. Competent chemists would have been forthcoming here in abundance years ago had there been any use for them. The majority of the chemical industries have had their rise in this country and there is no other reason for their translation to Germany than the failure of our capitalists and business men to appreciate the value of skilled labour—to their almost complete ignorance of science. The same is true of engineering. Until the engineer recognised the value of theoretical training, few engineering students were attracted to the schools and the schools could not develop; now that this is no longer the case, students are flocking to the schools in large numbers. The slow rise of the electrical industry in this country is largely a consequence of the want of theoretical training, which rendered our engineers slow to appreciate the great advantages which electricity offers. Even now the value of theoretical training is far from being appreciated by engineers; there is no class of student to whom a thorough understanding of the methods of research would be of greater value.

It will be very difficult for us to make the necessary changes in time, as we are so unwilling to call in the services of experts. The control of our educational system rests almost entirely in the hands of politicians and benevolent amateurs. And the dominant party unfortunately are opposed to progress, although ostensibly engaged in promoting it. They have been for the most part trained at the old Universities—and are imbued with their ideals; and if not unacquainted with practical methods, have but slight sympathy

with them. Academic ideals prevail almost exclusively.

The Universities could make the movement real, effective and universal to-morrow, almost by a stroke of the pen, if they would take stock of the situation and agree to reform their methods, so that their teaching might be in accordance with the requirements of the times. Their action would influence the nation forthwith. After all, whether we advance or not is mainly a question of attitude. The power is there to do the work; the alterations required in the machinery could be rapidly decided on, as the rough plans are already drawn and in many hands; all the necessary changes could be made—if there were only the will to make them—if we could only recognise what Carlyle recognised and preached sixty odd years ago, that "the old empire of routine has ended; that to say a thing has long been is no reason for its continuing to be"—if only the Japanese example were followed and a revolution effected in certain of our social habits.

Half a dozen strong and sympathetic men at the Education Department, with power to act and supported by Government, could solve the problem in a very few years.

VI

THE PLACE OF RESEARCH IN EDUCATION AND OF SCIENCE IN INDUSTRY

THE address on Art Tuition delivered here recently by Professor Herkomer—which I trust many of you had the advantage of listening to—was full of wise counsel which cannot fail to be of value to those who study it; the more so as Professor Herkomer is not only himself an artist of wide and varied experience, highly gifted with originality but also an experienced teacher and is therefore better able to advise than are most other artists. For, after all, only the competent teacher is fully aware of the difficulties which beset the path of the student.

But no advice given by Professor Herkomer was equal in importance to his opening statement—which was subsequently confirmed by members of the governing body—that in this Polytechnic *a clean beginning has been made in Art;* that you have advisedly elected to be free from all external control and are possessed with the fixed intention of working out your own salvation. Professor Herkomer begged—prayed I may say—that you should be kept clear of all contagion; and all who are your true friends must join in this prayer.

I desire to preach from the same parable as regards the teaching of Science—to exercise the functions of a Medical Officer of Health for Science; but my task is a difficult one. Professor Herkomer spoke to willing ears; his meaning was clear; he was dealing with a popular subject of which we all have some understanding. I cannot but recognise that my subject is generally misunderstood and its public importance greatly underrated in consequence. Some inscrutable influence has led those who have organised this Institute to appreciate the needs of Art: having had the wisdom to take proper advice, they have put you in possession of the elements of a perfect system of art sanitation; but the needs of the sister subject Science have yet to be grasped here and elsewhere. The sanitary condition of the dwellings which Science has to put up with throughout our country is most faulty, ill-arranged, out of date and oftentimes abominable; and if this Polytechnic, indeed Polytechnics and schools generally, desire to place the teaching of Science under healthy conditions, heed must be given to the inspector's warnings.

I might almost take Professor Herkomer's address, write science for art, add a few passages here and there and redeliver it as my own. Decorative art, that art which enables artists to decorate, you were told cannot be taught on the large scale, it cannot even be taught in schools—it must be taught in the workshop. Decorative science, science which decorates its possessor and enables him or her to be scientific, scientific knowledge which can be made use of in the service of the world, also cannot be studied except in the workshop and in Nature, to whom also the artist must resort. As Professor Herkomer said most truly:

all technical education will fail if established on a scheme in which the master's personality is eliminated, and that must follow in any scheme of wholesale tuition.

What meaning have the words science and scientific in English ears generally? Do they excite visions of a complicated picture of things concerning our daily life in its minutest details? Certainly not! Their utterance before those who know a little chemistry recalls fireworks and smells and perhaps simple salts; whilst those who take an interest in electricity have thoughts of bells ringing, galvanometer needles wagging or glowing electric lights; and teachers dream of South Kensington certificates and hardly earned grants. In the minds of the general public they call forth no response, especially in those of that very numerous section of the community which is concerned in commercial transactions and has no knowledge of manufactures. Science in the eyes of the average Englishman consists of a new-fangled set of ideas, all very well for those who can afford the time to study them but in his opinion not of such daily practical importance that it is necessary for the nation to pay attention to them. And this unfortunately is the opinion even of "educated" men and of many men of culture. This is perhaps the primary defect in our system to which the Medical Officer of Health for Science is bound to call attention; it is one which we must all unite in overcoming and which Polytechnics such as this should do much to remove.

If public appreciation of scientific procedure can be secured to even a moderate extent, a complete popular victory for those who press for its introduction must soon follow; the advantages to be derived from

the general application of scientific method to the affairs of life are demonstrably so great that when once they are made known at all commonly its adoption will be insisted on.

Science is but exact knowledge and there are as many branches of science as there are of exact knowledge. Remember, however, a loose incoherent body of facts does not constitute a science—a man who is merely possessed of such facts is not scientifically trained. A scientific man is a "knowing man"—not merely a man who knows but one who is properly described in the terms of the popular expression—He's a knowing fellow—which implies something more than the mere possession of knowledge, namely, the power to use it properly and with effect. There is every difference, in fact, between the scientific and the merely learned man. To be scientific is to be as far as possible exact in thought, deed and word; to act with a purpose and after due and careful consideration; to be observant and thoughtful; to be logical and methodical; to be guarded but fearless in opinions and judgment: and it is because we are so rarely all these that we are so rarely truly scientific.

Unfortunately the word science is now associated in the popular mind with certain branches of natural knowledge and it is because these are generally regarded as of importance only to those whose special business it is to attend to them that the proper application of the term is lost sight of.

I am not here to speak of science teaching—I do not know what that is—but of *scientific* teaching; of the method of teaching scientifically, that is to say, exactly and properly. I am really speaking on the

very subject on which Professor Herkomer dilated; we are both pleading one cause although on behalf of somewhat different interests; and mine is the wider plea and will, in fact, include his. He was the advocate of a practical workshop method of art tuition, under a teacher free as well as competent to consider the peculiar qualities and requirements of his pupils; of a method of so training students as to develop to the utmost their individual innate talents, instead of turning out a set of mechanical automata, blind followers of fashion. I desire to urge that whatever we teach, our method shall be scientific, so that students, in proportion to their abilities, may learn to apply honestly and usefully whatever knowledge they may become possessed of.

Institutions such as this have a great field of usefulness before them if all their work be done from such a standpoint; if it be not they will be absolute and costly failures. I much fear that unless a change in policy, almost amounting to a revolution, take place in many of the schools throughout the country, devoted to what we are now pleased to call technical education, the results will be disastrous.

Let us consider what has been and is being done. Until about twenty years ago, besides our Universities, the three London Colleges and Owens College, Manchester, the country had little to boast of in the way of institutions for higher learning to which those who had left school could resort; but then important University Colleges were founded in rapid succession in a number of the chief provincial towns. Meanwhile the educational fever spread to London and there assumed an extremely acute form under the name of Technical Education. The City and Guilds

of London Institute was founded and built first the Finsbury Technical College and later the Central Technical College at South Kensington, besides establishing an Art School at Lambeth; and by taking over, fostering and largely extending the system of Technological Examinations initiated by the Society of Arts, the City Guilds Institute exercised an extraordinary influence on the establishment and conduct of evening classes for instruction in technical subjects throughout the country. A further development of the same spirit has led more recently to the erection here, there and everywhere throughout London of Polytechnics, etc., and of a large number of technical schools of various degrees of importance in the provincial towns.

Why, it may be asked, all this educational activity and why especially did the cause of technical education so suddenly spring into prominence? The answer is, you know, because the conviction arose that our manufacturing industries were being seriously threatened in consequence of our failure to avail ourselves sufficiently of scientific aid and of the greater appreciation by foreigners of the services of scientifically trained workers. Because a feeling was abroad such as was graphically expressed by Huxley in a remarkable letter to the *Times* at the close of 1886 in which he pointed out that we had "already entered upon the most serious struggle for existence to which this country has ever been committed," adding "the latter years of this century promise to see us embarked in an industrial war of far more serious import than the military wars of its opening years. On the East, the most systematically instructed and best-informed people in Europe are our competitors; on the West, an energetic

offshoot of our own stock, grown bigger than its parent, enters upon the struggle, possessed of natural resources to which we can make no pretension, and with every prospect of soon possessing that cheap labour by which they may be effectually utilised. Many circumstances tend to justify the hope that we may hold our own if we are careful to organise victory."

The question is—have the steps we have taken to protect ourselves, to hold our own, to organise victory, led to success? In most cases, most certainly not! We are fast proving ourselves to be incapable of holding our own in almost every branch of industry.

Of course there are certain brilliant exceptions to the general rule but these only prove the rule and enable us to understand the cause of our failure.

Why is this? It is, I believe, because our character is so firmly set that nothing but severe compulsion will lead us to reform; it is because, whatever we may term ourselves politically, we are all by nature ultra-conservative, the rankest political radicals amongst us being the strongest conservatives in their general conduct. It is due to our intense belief in ourselves, the outcome of a long period of unexampled prosperity. We are so intolerantly individual that we cannot bring ourselves to organise and co-operate and this inability is probably the main source from which our difficulties spring. Let me take an illustration from agriculture, the most important of our industries but one which, as all know, is in a terribly depressed condition. We are told that last year (1894) £36,000,000 worth of butter, cheese, eggs, hams, bacon, fowls, ducks, etc., was *imported* into this country! Surely we ought to be capable of producing most of these.

As a matter of fact we cannot even make decent

butter or cheese yet. As Sir Henry Gilbert, the distinguished agricultural chemist, remarked to me lately when we were sitting together at dinner: "In our village we prefer to buy Brittany butter rather than the local 'Best Fresh.'" If we could do such things, it would not be necessary for the Yorkshire College, our leading University College, to send out peripatetic teachers to instruct dairymaids or for County Councils all over the country to do similar work, nor would the Duke of Devonshire have been called on as he was a few weeks ago to open a Midland Dairy Institute. In France they have long known not only how to make butter properly but what to do with it when they have made it—an important art which we, from our inability to organise, have also yet to learn.

Again, to illustrate why we are beaten by others, let me refer to the fate that has befallen what was formerly an important English industry—the manufacture of colours from coal-tar, which is now practically in the hands of the Germans and Swiss, so much so that Dr. Caro, the chief living authority on these matters, in addressing the German Chemical Society a couple of years ago was able to refer to it as a German national industry.

It was established in 1856 at Sudbury, near Harrow, by Perkin, who discovered the first aniline colour in the course of a research which he was carrying out, with purely scientific objects in view, under the direction of Hofmann, then Professor in the Royal College of Chemistry, in Oxford Street, London. Soon afterwards the important firm of Simpson, Maule & Nicholson was founded at Hackney Wick—Nicholson being another of Hofmann's pupils. Although similar works were erected in France and Germany, the

main business remained in English hands during perhaps twenty years. Meanwhile Dr. Griess—chemist throughout his life to the celebrated brewers at Burton-on-Trent, Messrs. Allsopp—was carrying on researches on diazo-compounds, which he had begun as a student in Germany—one of the most remarkable series of scientific researches ever made; but these did not meet with full appreciation until 1876. In this year the firm of Williams, Thomas & Dower of Brentford introduced certain azo-colours into the market which had been made in their works under the direction of a most accomplished Swiss chemist, Dr. O. N. Witt, strictly in accordance with Griess's prescriptions. The importance of the step thus taken was not fully apparent here but it was in Germany. Dr. Caro, a member of the now world-renowned Badische Anilin und Soda Fabrik, near Mannheim on the Rhine, who had formerly been chemist to Roberts, Dale & Co., in Manchester—the personal friend of Griess—had been working in the same direction as Witt, and his firm shortly afterwards brought out azo-colours similar to those manufactured by the English firm. This time the seed had fallen upon fruitful soil: the Germans were theoretical as well as practical and at once saw that the application of Greiss's discoveries was likely to be productive of practical consequences. They largely increased their scientific staff—research became the business of the works and the industry expanded at an extraordinary rate, while the English manufacturers, remaining unteachable and having no proper scientific staff in their employ, were simply snuffed out.

And the story has yet another side—you have all heard of the turkey-red or madder dyes formerly

obtained from the madder plant which was very largely grown in France, Holland and Turkey. In 1868 two German chemists prepared alizarin, which is the chief constituent of madder, artificially from anthracene—a substance contained in coal-tar. Now Perkin, when a student with Hofmann, had worked with anthracene and seeing the practical importance of the discovery again set to work and anticipated Graebe and Liebermann in the discovery of a process of manufacturing alizarin. He at once began to make it artificially—his works prospered and during several years the production of artificial alizarin was an English industry. But Perkin made the unfortunate "English" mistake of working almost single-handed—the Germans, meanwhile, were silently but steadily working in their characteristic manner, studying every detail, and soon came to the fore and became masters of the situation.

Perkin's business is now continued as the British Alizarin Company. The conditions under which this firm is working are somewhat peculiar and such as to procure for it considerable advantages but the success which has attended its labours is sufficient to show that such an industry might be carried on with special advantage in this country if organised in the proper spirit. Several years ago I had the opportunity of visiting the works shortly after I had inspected the most fully equipped factory of the kind in Germany and I was agreeably surprised to find that the English works were distinctly in advance of their continental competitors, being able to deal economically with larger quantities. But whereas here the anthracene colour industry is much as it was, abroad it has expanded in various important directions which are proving highly remunerative, whilst the original madder dyes, although

produced in larger quantity than ever, are made at slight profit owing to the excessive competition that has arisen.

Now, artificially made dyes have all but displaced natural colouring matters, indigo excepted, even among so conservative a people as our Indian subjects; and the industry is of enormous importance, although not to us. We are so much behindhand in the race that there is little chance of our regaining a good place in the list of runners, even if we go fully into training with that object (compare Art. VII).

And not only dye stuffs are made from coal-tar. A whole list of substances of the greatest value in medicine are also now prepared from raw materials derived from tar; some of these have proved to be most efficient substitutes for quinine and the growth of cinchona bark in India and Ceylon has consequently ceased to be the remunerative pursuit it was. All such substances have been the outcome of researches carried out in the German Universities or in the still more highly equipped laboratories of the German chemical works. Moreover, of late years, Nature's perfumes have one after the other been forced to disclose their character to the pertinacious inquirer and have been claimed as victims by the chemical manufacturer—abroad; although here again the example was first set by Perkin, who in 1868 showed how *Coumarin*, the odoriferous principle of the Tonka bean, might be artificially prepared.

If we seek to understand our early success as well as our later failure in the branch of industry of which I have been speaking, it is not difficult to trace the former to Hofmann's influence and the latter to our want of appreciation of the inestimable value of the

services of such a man. In this connection I may be allowed to quote from my Presidential Address to the Chemical Society in 1894 the following passage in reference to the then recently published memoir by Dr. Caro on the development of the coal-tar colour industry:—

To those who can understand it, the story told by Caro is nothing less than an epic; but it is one the contemplation of which must in many ways sadden an Englishman, elevating though it be when regarded from the purely scientific point of view. Full and complete recognition of Hofmann's services to the industry characterises every page of the monograph and the only ground of complaint which some of us feel that we have against the writer is that his own great services are nowhere referred to. Wherever they received their early training, the true education which experience in the world alone gives was gained by both Hofmann and Caro while in the service of English masters; and it is an interesting problem for speculation whether, had they remained with us, our position would not have been a different one. Germany could scarcely have accomplished what it has done without them; but by years of patient labour her Universities had laid a broad and solid foundation on which alone such men could build. Here, such men had neither bricks nor mortar offered to them either by the Universities or manufacturers; and such is our disregard of theory in this country of "practical men," that we even now have not learnt the lesson which the contemplation of the success of German chemical industry teaches; shall we ever learn it properly? In London, at all events, we shall probably wrangle during years to come about the establishment of a University worthy of the greatest city in the world, which will set an example and help us again to do our fair share of the work which has been taken from us; and it will be years, apparently, before English manufacturers will all learn to spell the word chemist—and that it will acquire some meaning for them. But it is much to be feared that recantation may come too late and that the opportunity will have been lost. America, perhaps, will meanwhile have learnt the lesson also and the competition we shall have to meet will not be European alone; we have not only to go ahead as fast as others but to make up

for much lost time; and it is not likely that others will calmly stand by while we make the attempt.

Such is the lesson which we may derive, it seems to me, from the study of Hofmann's career and the attendant circumstances; and it is one which we in this Society must take very deeply to heart.

At the present day, no matter what his business, the German manufacturer seeks to understand every detail and he is always trying to improve his processes. He attains this end by availing himself very fully of the services of men trained *scientifically* at the University, men who have all served their apprenticeship in the school of research; in fact, no man who has not been so trained is looked at nowadays by the German manufacturer.

In proof of this I may quote words used by Dr. O. N. Witt, now Professor of Chemical Technology in the Berlin Royal Technical High School, the most important institution of its kind in the world, in his report to the German Government as their commissioner at the Chicago Exhibition in 1893. Says Dr. Witt: "What appears to me to be of far greater importance to German chemical industry than its predominant appearance at the Columbian World's Show is the fact which finds expression in the German exhibits alone that industry and science stand on the footing of mutual deepest appreciation, one ever influencing the other; by affording proof that this is truly the case, Germany has given an indisputable guarantee of the vitality of its chemical industries."

Our policy is the precise reverse of that followed in Germany. Our manufacturers generally do not know what the word "research" means; they place their business under the control of practical men, often

admirable men in their way, possessed of much native wit but untrained and therefore too often and necessarily unprogressive; and such men as a rule actually resent the introduction into the works of scientifically trained assistants. Hence there is no demand here for men who have been carefully trained as investigators; consequently our schools do not seriously attempt to train investigators; in this country such people are only born and grow spontaneously, the high-class manufactured article is made in Germany alone. We elect to sacrifice at the altars of the examination Fiend, for God he cannot be called; and do our best to discourage the development of originality.

Let me give an illustration to make my meaning clearer. Recently I met a friend who has not only distinguished himself by his intelligent criticism of a particular industry but has become so interested in it that, having means at his disposal, he has himself become a manufacturer, affording a rare illustration of enterprise. I said: "I trust you are going to work on German lines and engage a good chemist to study your material systematically and so ascertain how its properties vary with its composition; for I have reason to think from direct experience that much is to be learnt in this way which will make it possible to put the manufacture on a scientific basis." His ready answer was: "Oh, I've got to make the business a commercial success!" Of course I understood what he meant whilst I felt that he could not fathom my meaning—he was too much an Englishman to do that. No doubt he will place his business in the sole charge of a practical man and as long as it suffices to look only at the surface he will succeed; but then, not improbably, the Japanese will come in and beat him,

for they have shown the world that they can organise as well as appreciate scientific method.

Or to give another example showing what may be accomplished under English conditions by adopting foreign methods, let me refer to work done by Dr. Mond, so well known in this country on account of the skill he has shown in developing Solvay's ammonia-soda process. Dr. Mond has long been engaged in seeking for a solution of the problem—how to burn fuel electrically, in such a manner, that is to say, as to produce electricity instead of heat directly. Having improved the gas battery devised in 1842 by (the late) Sir William Grove, in which hydrogen is burnt electrically, he was anxious to obtain a method of preparing hydrogen readily in large quantities. No good method is known but a mixture of hydrogen and carbonic oxide is easily made: eventually Dr. Mond found that on passing this mixture over heated nickel the carbonic oxide was converted partly into carbon and partly into carbon dioxide; and as the latter was easily removable he thus succeeded in a measure in effecting his object. In studying the very remarkable action which nickel had on carbonic oxide, it so happened that on one occasion when experiments were being made in his laboratory the escaping gas was led into the flame of a burner so as to set fire to it, a necessary precaution as the gas is highly poisonous; it was noticed that instead of burning as usual with a non-luminous smokeless flame it burnt with a slightly luminous flame. This strange circumstance led to inquiry being made and it was eventually ascertained that the metal nickel, under certain conditions, combined with the gas carbonic oxide, forming a very volatile colourless liquid: and thus one of the most remarkable discoveries of modern times

was made. The discovery was communicated to the Chemical Society in 1890 by Dr. Mond in conjunction with his assistants, Drs. Langer and Quincke. Having observed that the compound was very readily broken up into carbonic oxide and nickel, Dr. Mond at once set to work to devise a practical method of preparing nickel on the large scale from its ores through the agency of the new compound: after spending not only much time and labour but I believe also a very great deal of money on his quest he was successful in devising a process which he has carried out on the large scale during several months past, which has enabled him to produce over a ton of metallic nickel of almost absolute purity per week—perhaps the greatest achievement in metallurgy on record. Such action on the part of a native-born English manufacturer is "unthinkable;" at least I know of no precedent which would justify us in regarding it as possible under present conditions. I only recently heard of a firm who are doing work of a most important and critical character, involving the expenditure of a very large amount of money, who, having asked an expert whether it would not be well to carefully observe the temperature at which their operations were conducted, on being advised that it was most important to do so, objected that an instrument for the purpose, costing £25, was too expensive to use. The foreign worker would seek to know what happens at any cost.

If the English nation is to do even its fair share of the work of the world in the future, its attitude must be entirely changed—it must realise that steam and electricity have brought about a complete revolution, that the application of scientific principles and methods is becoming so universal elsewhere, that all

here who wish to succeed must adopt them and therefore understand them. It rests with our schools to make the change possible.

As the Secondary Education Commissioners point out: Education must ever become more practical—a means of forming men (they should have added, "and women") not simply to enjoy life but to accomplish something in the life they enjoy.

To this end, every school, I believe, whether in this metropolis or elsewhere, must work out its own salvation; and we must not look for payment on results or countenance examinations which reduce all to one dead level.

When Professor Ayrton and I were appointed the first professors of the City and Guilds of London Institute—he having cut his educational teeth in the service of the Japanese and I having been largely made in Germany—we found ourselves in complete agreement that we would have nothing to do with teaching for examinations. Those who afterwards became our colleagues in the establishment of the Finsbury Technical College, my friends Mr. (now Sir Philip) Magnus and Professor Perry fully shared this view and we all saw that a big problem in education lay before us which we could only work out if we had complete liberty of action; the Committees we had to do with never for one moment questioned this—all honour to them. I am proud to say that the programmes of the Guilds' Colleges have never been disfigured by references to examinations as objects to be kept in view by students and I venture to think that when the time comes to consider without prejudice the services which the City Guilds have rendered to the cause of education, it will be admitted that they, more

than any other body, have shown true appreciation of English needs. It is worth while noting that although it has never been a coaching college, the Finsbury Technical College has always been overfull, which disposes of the assertion that the bait of an examination must necessarily be held out as an attraction.

But what have the Polytechnics done? To what extent have they made *a clean beginning* in all subjects; and to what extent have they been suborned to worship at the examination shrine to earn the unholy money bribe called payment on results?

I am told that the latter course is adopted in some cases not because it is felt to be the right one but because it would not do for Polytechnic B to appear behind Polytechnic A in regard to the number of certificates gained—Governors might object! Unfortunately we know that such arguments are held, that quantity counts for more than quality. The English manufacturer can appreciate a big order but will not undertake to carry out a small one; and here the foreigner steps in and having made a beginning gradually improves his position until finally he is left in practical possession of the field. Perhaps if we attended more to quality in education there would soon be a large increase in its quantity. A large proportion of those who at present come forward to be prepared belong to Professor Herkomer's great class of those who ought not to be taught at all. Among these are the certificate hunters brought into existence by School Boards and other authorities. There is more than sufficient work to be done among those who are deserving and capable.

To quote Professor Herkomer: "No system could act more perniciously on the morals than payment on

results. A few schools have through their strong masters and, in some cases, strong local help, shaken off all the trammels of danger. The fact is, it has all grown into an unwieldy piece of machinery with all the deadening effect of *impersonality* in the teaching. The whole system, when it is not practically upset by a strong and independent master, is lifeless, humdrum and above all soul-deadening. It is the despair of the masters and the disappointment of the brighter pupils." To all which, I say, Amen!

The system was established at a time when the many schools to which I have referred were unknown and it was largely because the desired result was not obtained under the system that these new schools became necessary and were founded. How futile then must be any attempt to base the instruction in these new institutions on discredited methods—such old wine cannot be put into such new bottles. Time does not allow of my fully discussing this matter. I can only point out that the programmes of instruction on which the examinations are based are of such a nature as to make real instruction impossible—even if no other objection could be raised, the extent of ground to be gone over is so great as to make cram an absolute necessity. We have to bear in mind that Germany has prospered without such examinations, Japan also; I believe China is the only country in which a similar system meets with national support—recent events do not encourage us, however, to derive any consolation from this circumstance.

As Professor Herkomer points out: "Granted that the Kensington system was of use once upon a time and that without it schools of art would not have been established at all, we must look the matter straight in

the face and acknowledge that we have now arrived at a point when it must change its form in order to fulfil a great duty and to be of use or else be disbanded." Undoubtedly this is so and is equally as true of Science as of Art. The Department has at last perforce itself recognised the necessity of change but all too slowly and by appointing a certain number of inspectors has in a measure initiated a new policy. The very distinguished scientific man who is the Director of Science, in his evidence before the Royal Commission on Secondary Education, openly stated indeed that if he had his way he would entirely substitute inspection for examination in the elementary stage—but it is to be feared, unfortunately for the country, that in this, as in most other cases, one swallow does not make a summer.

Professor Herkomer insists that in the future freedom of action must be given to each master—to each town. This independence, he says, is to be obtained only by municipal and County Council aid. "Emancipation from the apron-strings of Kensington through municipal and County Council support would produce *an individuality*," we are told, "*in the art of each town*:" for which I may substitute, *in the way in which science was taught and applied in each town.*

But we must be careful that in leaving the science and art frying-pan we do not jump into a worse municipal fire, of which there is clearly some danger; for while all the world is engaged in decrying examinations, our County Council is bent on devising new ones. Scholarships at times are of great value to students, provided they fall into the right hands and are obtained as well as held under right conditions. But it is easy to give too many scholarships and still

more so to give them to the wrong persons. Unless the examinations are placed in very competent hands, not only will a serious injury be done to our general system of education by leading those who are preparing boys and girls to adopt methods which it is unwise to follow in schools and to force their pupils on unduly but the wrong people may be selected; the growth of a class of overtrained pot hunters may be encouraged instead of a vigorous, keen-witted, observant and resourceful race. Those who prove themselves the most apt scholars under the tutelage of the crammer, however able as desk workers, may in the end entirely disappoint the hopes of those who desire most to encourage the development of ability. Huxley has said much as to the importance to the nation of catching the potential Faraday but it is doubtful whether such would ever shine in a competitive examination in which among other tasks they were asked to write an essay on Oliver Cromwell or some other like topic equally remote from the daily experience of a healthy lad. If we depend too much on examinations we may easily select the unfittest for the work of the world; and unless very careful we are almost bound to select but one kind of ability—clerical rather than practical ability; unless indeed we altogether change our system of school education and examine very differently.

It is also difficult to understand what is to be gained by examining candidates for £5 evening scholarships; it must prove to be a very expensive mode of distributing such doles and it ought to be possible to find some other more practical way of selecting those whose studies would be materially promoted by such a grant.

Clearly, therefore, it is essential that we should not lose sight of the fact that an exceedingly complex educational system is now growing up under the influence of men who, for the most part, are in no sense experts and have but little knowledge of the details of such work, although possessed with the desire in every way to do service to the community and to improve our national position. It therefore behoves all who can follow such work to keep most careful watch on the march of events; otherwise those who seek to benefit may in the end do irreparable injury; the present is a most critical period in our history and such watchfulness is imperatively demanded of us.

I have ventured on this digression because so much depends on the foundation laid at school, as technical studies can only be satisfactorily engaged in by those who have been well trained from the beginning.

As Professor Herkomer says, the kind of individuality to be developed in each town—or in the case of our huge metropolis, in each district—will vary according to the necessities of the community. In future each Polytechnic in London must seek to ascertain what special work it can do to greatest advantage, instead of all following one example, as is too much the case at present. In words almost exactly those of my artist colleague: "This is the only way in which schools will obtain a direct influence over the industries of the country; and the influence will be the right one when the master is carefully selected, because it will be *the school around a man* and not a man struggling to be master in the midst of a system of impersonal teaching, where every student is expected to be squeezed into a great educational mangling machine." "Choose your master carefully," he says,

"but then let him *be master*, and he will soon, with freedom of action, vary his forms of tuition according to the idiosyncrasy of each student, or the necessities of his immediate locality. The one true prize to be worked for would be individual progress. All teaching must be on personal basis."

Choose your master carefully—this is indeed good advice. But this implies, of course, that those who have to choose know how—that they have some standard before them. Have they? Results seem to show that they rarely have. In this manner, as in many others I believe, the City and Guilds of London Institute has set a good example by selecting men known to be capable of doing research work; and a large amount of research work has been done in its Colleges. I am not aware that, excepting in the case of the Principal of this Polytechnic, capacity to undertake research work has been regarded as a qualification; on the contrary: for I know that when it was urged at one of them that a particular candidate had exceptional qualifications of this kind, the answer was: We want a man to teach, not to do research. The work of true education *is pure research*; really good teachers are engaged in nothing else, being constantly occupied in studying their pupils' idiosyncrasies, in devising suitable methods of instruction. The "reseacher" is the equivalent of the artist; the teacher who cannot engage in research is the equivalent of the inartistic copyist. No subject is at a standstill in these days—all progress involves research, although not always original research. The young child even is constantly engaged in research: the habit is only gradually lost at school under our highly developed modern soul-killing system of perpetual lesson-learning,

itself largely devised to satisfy a system of payment on results.

Let us hope, therefore, that every Board of Governors will soon learn to appreciate the national importance of research and will require evidence from every candidate for a teacher's post of ability in this respect —when such is the case, the research spirit will prevail also amongst students generally.

A most desirable example has been set in this direction by what, I suppose, may fairly be termed the least pretentious of the London Polytechnics—that in the Borough Road—which with the assistance of the Leathersellers' Company has just opened a branch tanning school at Herolds Institute, Bermondsey, and with unblushing effrontery, one may say, prints on the programme under "Tanning School" the words, *with special research laboratory*, and not content with this informs us on the next page that "the special research laboratory is fitted up and supported by the Worshipful Company of Leathersellers"—all hail to the Leathersellers, let us say! An industry which makes such a new start—very late though it be—and recognises the fact that research can help it out of its difficulties is phenomenal in this country but on the high road to retain its position if not to improve it.

I was much struck at the opening of the school by a statement made by the chairman, Mr. Lafone, M.P., who told us of an American customer who was in the habit of buying large quantities of a particular kind of leather here, of then taking it to America and manufacturing it, returning the goods here for sale. This man had remarked to him, he said, "that he had seen all our works and did not care a fig for our competition—for we had not even begun to know how

to make the best." The introduction of the research spirit is sorely needed to cure such an old-world state of affairs as this.

Of course, whenever I advocate research in this way and urge that the research spirit must be infused into all our teaching as well as into our national life, I am told it can't be done—that children can't solve problems. But there is a saying that an ounce of practice is worth a pound of theory—it is only a half truth and a saying which is often misapplied but it consoles me somewhat on such occasions. I *have done it* during the past fifteen years, since the opening of the Finsbury Technical College. No one has the right to say that it cannot be done until they have tried—all who really try, will succeed; those who do not should not attempt to teach.

VII

THE DOWNFALL OF NATURAL INDIGO

At the end of January last we were informed by telegram from Calcutta that the indigo planters were about to hold a large meeting there to consider the question of the union of the interests connected with the salvation of the industry. This seemed much like shutting the stable door when the steed was stolen; and the reports afterwards published in your columns of the views of the planters and of the steps that are being taken to promote the cultivation of sugar in place of indigo show that such is not far from being the case. Whether the belated action of Government in coming to the assistance of the planters, in combination with their own tardy efforts, will serve in any measure to resuscitate an industry which should never have been allowed to reach the brink of ruin, the future alone can decide. But it is necessary that the story of the downfall of natural indigo should be reflected on, as lessons of moment may be learnt from it; and I would beg permission, Sir, to refer to some of these in your columns at this period of comparative leisure.

The German Chemical Society early in the year issued to its members the full account of the proceed-

ings at the meetings held in Berlin on 20th October last (of which a brief notice appeared in your columns at the time) to inaugurate the opening of the Hofmann-haus, the future official quarters of the society, which has been erected by public subscription in memory of the great chemist whose scientific reputation was established in this country during the years 1845-1865 and whom we, fools that we were, then allowed to be attracted back to his native land, where he laboured with unremitting ardour and marvellous effect up to the very moment of his death in 1892. It is a sign of the times and evidence of deepest foresight on the part of those who had the arrangements in hand that at the evening meeting—the first meeting of the German Chemical Society in its new home—the subjects considered were the history of the discovery of the structure of indigo and of its artificial production both in the laboratory and on the large scale. The speakers were no mere reporters: but chief actors in the great indigo drama which has been playing on the German stage for now full thirty years—Professor A. von Baeyer, to whose practical genius we owe the wresting from nature of one of the most beautiful and remarkable of her perquisites; and Dr. H. Brunck, a director of the world-renowned industrial colour enterprise, the Badische Anilin und Soda Fabrik.

Professor von Baeyer's story, to those who can decipher its full meaning, is of indescribable interest, as in it we have displayed in logical sequence and rhythmic beauty the long series of conceptions by which the discoverer was guided; but the works-director's recital is an even more wondrous tale, telling as it does of the remarkable manner in which technical problems of extraordinary intricacy and difficulty

have been, one by one, met and fully solved. It is impossible to convey to those who are not instructed in such matters any idea of what has been done. I can only say that, as a moral lesson, as a story of unwearying patience and determination to succeed at whatever cost, as a display of scientific acumen, the story of artificial indigo appears to me to stand alone in the history of manufacturing enterprise. It will certainly serve as an example for all time.

Dr. Brunck tells us that up to the present his firm have invested no less a sum than £900,000 in the enterprise; and that the results they have hitherto achieved so fully correspond to their expectations that they hope to be victorious in the long and arduous struggle that is before them; in fact, they think it is merely a question of time when the entire consumption of indigo will be provided for artificially. No difficulty can arise in procuring the raw material, naphthalene, in sufficient amount; and as at present prices the value of the natural indigo produced may be set at between two-and-a-half and three millions sterling, Germany will benefit considerably from the operation: for that Dr. Brunck's confident prediction will be realised and at no distant date, there can scarcely be a doubt. Whether or not we agree to accept his conclusion that it may be well for India if the vast area now devoted to the cultivation of a crop so precarious as indigo be given over to the raising of food stuffs, rivalry conducted in the manner in which the German chemist and manufacturer have conducted this struggle must win our warmest admiration.

Of one thing we may now be certain—that if indigo planters desire to retain any share of the industry, they must not only seek to improve their

methods of cultivation and of extracting the dye-stuff but they must be prepared to refine the natural product and supply a practically pure article. Even in indigo dyeing the days of the rank empiricist are numbered and the certainty which attends the use of pure materials in fairly skilled hands will have its inevitable influence.

The truly serious side of the matter, however, is not the prospective loss of the entire indigo industry so much as the fact that an achievement such as that of the Badische Company seems to be past praying for here. And yet it might so easily have been otherwise. Let me give a few proofs. Among Hofmann's early students was a precocious youth named Perkin, who happily learnt some chemistry at school—the City of London—and quitted it before all practical ability had been educated out of him. He became Hofmann's pupil in his fifteenth year and was made an assistant in the research laboratory at seventeen. Hofmann taught his students to do and to think for themselves; the "tyranny of the book" was unknown in his school; and Perkin's ardour was such that he fitted up a laboratory at home, where he worked in the evening and during the vacations. The result was that in 1856 he discovered the first coal-tar colour and having secured a patent for it, commenced his career as a manufacturer in 1857, as a lad of nineteen—an age at which in these days our ancient Universities treat young Englishmen as schoolboys and condemn most of them to commune with the past instead of preparing them to work in the future.

While a student, Perkin was put to work with anthracene by Hofmann; and when, in 1868, Graebe and Liebermann made their great discovery of an

artificial method of preparing the colouring matter of madder from coal-tar anthracene, Perkin's attention was naturally again attracted to the subject. He soon entered the field with a practical process and erected works which rapidly grew in importance; in fact this industry also was first established in this country.

We can also claim priority in the case of a third class of coal-tar colours, the azo-dyes, which of late years have played a most important part in the dyer's art. They were discovered by Peter Griess, who came here as an assistant to Hofmann and then became chemist to Messrs. Allsopp, the brewers. Their manufacture was first systematically undertaken by Williams, Thomas, and Dower at Brentford, under the direction of Dr. Otto Witt, a distinguished chemist, now professor in the Berlin Polytechnic.

Nevertheless, the part we play in making all these colouring matters at the present day is ridiculously, not to say disgracefully, small. And the reason is not far to seek. Let me give an example. A few years ago Mr. Green, chemist to one of our English firms, discovered a new coal-tar dye, which, when put on the market, was most favourably received. But no proper scientific staff was available in the works to extend the invention and little encouragement was given to the inventor; consequently the dye-stuff bred few descendants here. The firm did not even patent the invention: vainly thinking to keep it secret. The result was that within a few weeks the nature of the new material was ferreted out in several foreign laboratories: not only was the dye-stuff manufactured but it was realised that a new field had been opened out and quite a number of valuable similar dyes were produced and patented. Here the counting-

house could not appreciate what the laboratory had done.

Perkin also, like most Englishmen, was too much of an individualist and did not sufficiently appreciate the tremendous powers of the angel of research under whose guidance he had worked so successfully; in fact he did not surround himself with a sufficient scientific staff fully to exploit his inventions. In Germany, laboratories superior to those in the Universities were erected in the works and research was prosecuted in every possible direction; consequently invention followed invention and, more important still, a reciprocal effect was produced on the Universities. Being able to dispose of their products—students trained in the methods of research—indeed to obtain a high price for them, their business also grew apace; and by liberally subsidising the workers in University laboratories the manufacturers also secured their full co-operation.

In Germany the State is fully alive to the value of science; here it is not. One of Hofmann's earliest assistants in London was Mr. Abel—the present Sir Frederick Abel—who afterwards became chemist to our War Department. In the latter capacity, having acquired from Hofmann the habit of "researching," he naturally applied himself to the study of gun-cotton; the results of his investigations were embodied in important monographs submitted to the Royal Society in 1866 and 1867. This work was the basis of the method since followed in making gun-cotton on the large scale at the Government works at Waltham Abbey. Bearing in mind the enormous importance the manufacture has assumed, especially since the introduction of smokeless powder, it was to be supposed

that our Government would have felt impelled to secure the services of a highly-qualified staff thoroughly to investigate every point in connection with such a subject as that of explosives and to maintain themselves in advance of outside knowledge; that they would follow the example set even by the smaller Continental manufacturers and seek to obtain control to the minutest detail over a business of such national importance. As a matter of fact, nothing of the kind has been done and I believe that we know (officially) but little more of the subject than when Abel left it. Such a policy is fatuous folly. The manufacture of explosives is now a branch of organic chemistry. This has in no way been taken into account in appointing the Committee on Ordnance now sitting. The chemists on it, although most eminent in their own special fields, are ignorant of organic chemistry and cannot well appreciate its mysteries. It is difficult to understand how their judgment can be "proportionate"—to use Faraday's expression—on some of the subjects that will necessarily come before them.

One of the most important operations in the indigo process is the oxidation of naphthalene by means of sulphuric acid, which becomes converted into sulphurous acid; the latter is then recovered and reoxidised to sulphuric acid. The oxidation of the naphthalene is therefore effected practically by atmospheric air. The fact that the Badische Company have elaborated a process which enables them to convert sulphurous into sulphuric acid cheaply, without the use of the well-known cumbersome lead chamber, according to Dr. Brunck, is an essential feature of their success in manufacturing indigo. In Germany the process of making anhydrous sulphuric acid from oxygen and

sulphurous acid is supposed to have been originated by Winkler in 1875. But I well remember a communication being made to our Chemical Society early in 1876 by Messrs. Squire and Messel, in which the process was independently described. It had been patented by Dr. Squire in the previous year. Dr. Messel's firm were for many years the chief makers in the world of sulphuric anhydride and have gradually improved the process, so that for some time past they have been able to manufacture the acid from the anhydride, instead of the opposite—an extraordinary achievement at which I know my friend Dr. Messel has long aimed. Having more than once had the privilege of visiting the works, I know that their machinery was far in advance of any other similar works up to within quite a recent period. I quote this merely as proof that English soil is not unconducive to the development and maintenance even of complex chemical processes, when only the opportunity is given and the commercial element assumes its proper place and does not usurp complete or exercise unintelligent control. Dr. Mond's wonderful success in working the ammonia-soda process and other cognate inventions, and his marvellous nickel process, are further striking proofs of this proposition.

When I ponder over Dr. Brunck's story—when I look back along the thirty years of my own experience and consider what has happened and what I know from personal study of the organisation of industrial enterprise here in comparison with Germany and the United States—I am aghast at the prospect before us. The country is full of scientific ability, capable under proper conditions of doing all that—perhaps more than—is done elsewhere; but the public will not

utilise it and academic traditions dominate our schools and Universities. The reform of public opinion, of the public attitude, is the reform we most sorely need. There would seem to be an almost entire absence of what may be termed public common sense—an almost complete absence of public appreciation of what is going on in the world and which constitutes the real struggle for existence, of the revolution in method the pursuit of science has brought about during the Victorian epoch. The success of Germany is in no way primarily the outcome of technical education in the sense in which the term is understood in this country but is mainly due to the fact that the Universities have done their duty and that the nation is educated. Their Universities have always been schools of research, of inquiry; unless and until ours become such and our youth are trained to advance, there can be no hope for us. God help us to make the change before it be too late!

VIII

SCIENCE IN EDUCATION—THE NEED OF PRACTICAL STUDIES

I heard a thousand blended notes,
  While in a grove I sate reclined,
In that sweet mood when pleasant thoughts
  Bring sad thoughts to the mind.

To her fair works did nature link
  The human soul that through me ran,
And much it grieved my heart to think
  What man has made of man.

WORDSWORTH.

"LA science domine tout: elle rend seule des services définitifs. Nul homme, nulle institution désormais n'aura une autorité durable s'il ne se conforme à ses enseignements." Such is the opinion propounded by one of the most distinguished French *savants* of the day, the veteran perpetual secretary of the Academy of Sciences, M. Berthelot, in the preface to his work, *Science et Morale* (Paris, 1897): and it would be difficult to express the claims of science to consideration in more unqualified terms. Matthew Arnold, although he had no scientific proclivities, was a determined advocate of the introduction of the scientific spirit into education—indeed, he proclaimed

"the want of the idea of science, of systematic knowledge," to be "the capital want of English education and of English life." If the advice he tendered, in the closing chapters of his *Schools and Universities on the Continent,* in 1868 had been followed, we should not now be called on to lament our present most deplorable condition of backwardness.

> The ideal of a general liberal training is to carry us to a knowledge of ourselves and the world. . . . The circle of knowledge comprehends both (the study of the humanities and the study of nature) and we should all have some notion, at any rate, of the whole circle of knowledge. The rejection of the humanities by the realists, the rejection of the study of nature by the humanist, are alike ignorant.

So wrote Arnold; but to the present day such doctrine has failed to secure more than sporadic recognition. We pay no attention to prophets—and it is doubtful if we shall ever give heed to any one short of the Destroying Angel.

Yet, although the value of science to the community has been insisted on for years past by men whose opinion is deemed of special worth, although the need of teaching science in schools has been preached *ad nauseam,* authorities still affirm that no proper heed is paid to the advice tendered so copiously and that the country is in sore danger from its neglect to notice the writing on the wall: for our competitors are said to be availing themselves far more than we are of the methods of science and to be conducting their industries with most careful regard to the principles underlying them while we remain steeped in empiricism; and not only their industries but also their institutions, as their Governments are utilising in every possible way the services of scientific advisers, with

whom they seek to place themselves fully *en rapport*. Sometimes we are encouraged to hope that the awakening is at hand. Only a few months back, owing to the disturbing character of the reports from the seat of war, a shiver of horror passed through the nation at the possible consequences of lack of scientific training in our officers; but the wave soon spent its force and we are now willing to attribute the break-down to anything but the right cause—the absolutely vicious system miscalled education adopted in our schools.

Where is the remedy to be found? It would seem to stand to reason that we should be trained to do our work in the world skilfully, honestly, fully and faithfully. But are we? How can the study of a few books in a more or less formal and perfunctory manner be an effective preparation for life? Life presents an infinite number of opportunities and calls on us to perform a multitude of duties; and we live our lives not merely among men and under the rule of men but subject to the presence and omnipotence of Nature. The control of education is still in the hands of the humanists alone. We need to remember that the control was secured by them in pre-scientific times, when Nature was perforce acknowledged but in no wise understood and before man had acquired the marvellous power he now possesses of utilising her forces—forces, it must be admitted, which in no way strike the ordinary individual as remarkable, owing to his entire ignorance of fundamental principles and his want of imagination. But something more than the mere teaching of science is needed. The problem is a far wider one—our whole system of education needs to be put on a scientific basis.

Looking from a distance, the rigid separation into castes which obtains in India and the impossibility of overcoming caste prejudice there strike us as remarkable. But we are ourselves as much the victims of a caste system as any people in the world. The "knowledge caste" is keeping back our whole nation and will land us in perdition unless we can dispossess it from the seat of authority and reverence. Do not let it be supposed that this is the view of a modern revolutionary; it is sane, crusted doctrine, supported by the highest authority, for it was preached by an eminently respectable member of their cloth to teachers many years ago—by Thring, who brought Uppingham to the front rank as a public school and whose constructive power as a teacher has yet to be appreciated.

To put education on a scientific basis, we must, in the first instance, depose the knowledge idol and its attendant evils; the knowledge caste must be removed from their position of predominance; we must cease to reward and pay reverence to the knowledge misers and we must appreciate them at their true worth—as purely selfish creations.

And yet we need in no wise despise mere knowledge or cease to avail ourselves of it—on the contrary. But the true functions of books must be understood. We must learn to use books with skill and with reverence—not mechanically. We must see in books sanctuaries of knowledge ever open to us as sources of information and inspiration—of power. In olden times the Sagas were committed to memory, because they could not be written down. Why should we perpetuate a custom which has so entirely lost its motive and commit whole text-books to memory?—be it noted, as a rule, only for a sufficient length of

time to satisfy the unhealthy and unreasoning demands of the examiner, who almost invariably is guided only by the formula, "Facts, more facts, all the facts in the world." Surely we should rather follow Prince Kung's advice (p. 13), and be ever mindful that "when principles are understood, their application can be extended."

To impress on us the folly of wasting mental effort, we need a science of literary economy of which this will be the guiding principle. In these days, boys and girls are not taught at school to read—except mechanically: their assimilative powers are impaired almost beyond recovery by feeding them on highly condensed, already digested food: for the modern primer and text-book are creations of the enemy and too often destructive of all power of self-helpfulness. In fact we do not yet realise that just as the craftsman has been destroyed by the introduction of machinery, which confines each workman to the production of some one piece, so has the introduction of the text-book destroyed the scholar.

But even when wisely used and of the best, books alone will no longer suffice us; their place in modern education must be a subordinate one, as we cannot with their aid fashion that practical skill the exercise of which now distinguishes civilised mankind; and they afford no assistance in reading the great book of Nature.

To state the school programme of the future in a word, it will be to develop *knowingness*—not to inculcate knowledge. We must send our boys and girls out into the world trained to use their eyes and think for themselves and with some power of helping themselves, with some inventive skill—not as eyeless,

thoughtless, helpless dummies, crammed with useless knowledge but with wits educated out of them, too often destitute of all ability of exercising either initiative or judgment.

The subjects of instruction must be chosen so as to develop knowingness in all necessary directions, domestic and public. In no case must exclusive possession be granted to either party: humanist and realist must share the field equally and from the outset of the school career.

Three classes of studies claim consideration—literary, practical and mathematical. It is well understood what literary studies include. It remains to consider what are to be regarded as practical studies—experimental science, manual work, drawing and physical exercises must all rank under this heading. Hitherto practical studies have received no proper share of attention—more often than not, none worthy of mention. In future they must be placed on no less than an equal footing with literary studies. In the past, literary studies have monopolised attention because originally education was provided solely for the recluse; the man of action confined his attention to practical studies and gained his knowledge in the world. The recluse no longer counts. Why, then, should a system continue to prevail which was devised solely in his interest?

The struggle at once begins, however, when we seek to give to practical studies their proper place. The humanists—the party in power—will not see that they have a very imperfect comprehension of the world of to-day and that they arrogate to themselves a very unjust share of the school time. "Not only are men trained in mere book-work ignorant of what

observation means," says Huxley, "but the habit of learning from books alone begets a disgust of observation. The book-learned student will rather trust to what he sees in a book than to the witness of his own eyes." No statement more to the point could be made; yet it is only the few of us who have been called on to deal with book-learned students and to endeavour to interest them in practical work who can testify to its truth and fully appreciate the deadly consequences of unquestioning and exclusive devotion to books. It can scarcely be doubted, however, that this is precisely the attitude which checks our progress.

Moreover, the humanists must be led to see that their work, however well done, will not suffice to rear a complete edifice. Indeed, in some respects, the better it is done the more subtly undermining is its influence. We are accustomed to hear Latin and Greek praised above all other subjects; to be told that the minute attention to niceties of grammatical construction and shades of meaning which the exact study of these languages entails is of the highest educative value; that the fact that they are dead languages and therefore unalterable gives them an immense superiority over living languages as subjects of study. But great as are the advantages they undoubtedly present, for these very reasons classical studies tend above all others to create in the mind of the learner a belief—an almost blind belief—in precedent and authority. "What is the rule?" is the first question to arise and the thought never occurs that there may be a new "rule" to be discovered: therefore, the more carefully and thoroughly the classical languages are taught, the more necessary is

it to introduce a corrective and to require that attention be also seriously paid to subjects which tend to give greater breadth to the mind by cultivating powers of individual observation and what may be termed external activities.

It may be added here that although of inestimable value in its way, mathematical training also has a narrowing tendency—so much so that the effects it produces need to be even more carefully corrected for: perhaps no one tends to follow precedent more closely than the mathematician—the formula is his god. But the introduction of practical methods into mathematics seems destined to work a revolution and to deprive the subject of many of its objectionable features, whilst heightening the value of those which render it so indispensable an instrument of elevated and intense thought when its higher branches are cultivated.

Flexibility of mind and power of adapting oneself to new circumstances and conditions are the qualities required at the present day; the study of living languages and of the manner in which changes have taken place and are taking place in them affords discipline of the very highest value from this point of view. Thring, who was always a humanist, advocated before all things the thorough teaching of language; but language was to be taught as a means of developing powers of thought and of imagination. And Thring, though a humanist perforce of early training and the influence of tradition, was yet a realist at heart. This is shown by the fact that he enforced the doctrine of "thinking in shape," thereby rendering a service of inestimable importance to education, the value of which has yet to be generally appreciated;

for the doctrine spreads but slowly and is nowhere thoroughly professed. Thinking in shape involved for Thring the formation of a complete mental picture of the subjects studied and as one means of securing this he advocated the continued use of proper pictorial illustrations. The importance he attached to such illustrations is shown especially by his advocacy of the pictorial decoration of schools and by his statement that the day is yet to come when it will be acknowledged that the invention of photography is equal in importance to that of printing. When Thring's doctrine is properly applied, apart from the advantage accruing to literary studies, much will have been done to bring about a natural blending of these with practical studies. And a great step will have been taken towards developing sound artistic tastes.

Another argument for diminishing the relative importance of literary and particularly of classical studies in favour of practical studies, especially in science, is that the former cannot be carried out without the latter. As Huxley says, "No man will ever comprehend the real difference between the ancient world and our present time, unless he has learned to see the difference which the late development of physical science has made between the thought of this day and the thought of that."

And for yet other and even higher reasons it is essential that we should accustom our scholars to be practical. In the first place, it behoves us to remember Carlyle's dictum that "man is a tool-using animal." His power depends on the use he can make of tools—of machinery generally. To use tools involves using the hand and eye in conjunction—and not alone but guided by the mind; and the use of

tools almost invariably involves action also—involves more or less moving about. Literary studies are desk studies; nearly all the conventional school work is done at the desk, which is an inheritance from the cloister, not from the field of action. Boys and girls are therefore systematically trained at school to habits of inaction. No observer of our young people can fail to be struck by the fact of their mechanical helplessness — their unwillingness to bestir themselves except at games, their want of purpose, the absence of discipline or capacity to take an instruction, their want of consideration for others, their general inactivity and need of a leader—all indications of thoughtlessness. Of course there are exceptions but these are almost invariably traceable to innate genius, which nothing can entirely repress. The state is certainly an acquired one, the outcome of our unnatural system of education — unnatural because it so partially provides for our requirements; and it cannot be allowed to continue. We talk much in these days of introducing technical education: but we forget that we have as yet no system of general or liberal education; that our present system is a system of highly technical education devised in the past to meet the requirements of a privileged and special class — of the scribes and dialecticians, not of those who were to do the practical work of the world.

The doctrine of the humanists, as stated by Matthew Arnold— "to know ourselves and the world"—cannot be held to shut us out from the exercise of all but mental activity. It should rather include the full development of mechanical aptitudes. No person can be said to have had even the rudiments of an

education whose faculties have not all been in some way developed. And taking into account the narrowing conditions under which we work, it is daily becoming more and more necessary that the attempt be made to correct their natural and inevitable effect by practising those very exercises which these conditions tend to put outside our experience.

To carry out any such programme as that sketched, if we are to put our system of education on a rational and scientific basis, all concerned must carefully and honestly face the facts and seek to determine what are essential changes to make; having decided on these, they must endeavour to put them into operation, whatever the cost. The question is of imperial importance and cannot any longer be played with. If we are prepared to admit—as I believe we must be—that we do not know what is the right plan to adopt, there is only one honest course open to us: to confess that such is the case and at once set to work to experiment in order to develop a new system in fair accordance with our requirements. As yet we have done nothing but temporise and tinker; we must reconstruct the machine, not patch it. Unfortunately, the country is held back, not only by its indifference and failure through ignorance to appreciate the gravity of the situation, but also by a blind belief in the competency of those who conduct education.

> The present is enough for common souls,
> Who, never looking forward, are indeed
> Mere clay, wherein the footprints of their age
> Are petrified for ever.—LOWELL.

We forget that our teachers are not only brought up under false and narrow conditions but also work under such; that his very office withdraws the teacher

from the world and makes it almost impossible for him to keep in touch with or even understand its practical requirements, besides encouraging in him an overweening sense of self-confidence. Then it is characteristic of us that we never make rational trials to find out what is the right course to adopt: we believe rather in blundering into it, sooner or later, in some unforeseen manner. "Let others make experiments: we will reap the benefit of their experience," is too often our selfish attitude. The manufacturer declines to introduce a new machine, arguing that something better will soon be invented and that it will be as well to wait for that. And whilst willing to spend millions upon millions on new ships, our Government will not grant its Chief Constructor a few thousands to make experiments which might result both in great improvements and in great economy. Being fed only on authority and precedent at school, we never learn to experiment: therefore we do not know what an experiment is — let alone appreciate its value and importance. When our educational house is to be put in order, we rush abroad to see what others are doing who are working under conditions different from ours, instead of treating the problem scientifically by carefully defining our special requirements and seeing how we may meet them. Still, this matters little, as we have shown that we are not even to be shamed into doing better by the example of others. But if we are to save the nation, we must in some way give up the game of vested interests and play advisedly for the really serious stake —our continued existence as a Power of importance.

One consequence of breaking down the knowledge idol—the first necessary step in the way of reform—

I believe will be that we shall cease to be slaves to a rigid time-table, at least in the earlier years of school life. When school-days are over and we engage in some occupation, we do not chop our lives up into three-quarters of an hour sections during each of which we do something different. On the contrary, we engage in some task and do incidentally whatever is necessary for the due performance of that task. School, therefore, affords no proper preparation for the work of life: the child cannot, as a rule, pass naturally from the one to the other. Probably much would be gained by assimilating school methods far more closely to those of ordinary everyday life. Certain arts must be acquired at the beginning of the school career and may well be taught, perhaps, during specified intervals: thus every one must learn to read, to practise the graphic arts—writing and drawing, which should be treated as one—to do simple sums in arithmetic. But when once an elementary understanding is gained of these, the further instruction might well be largely incidental rather than specific, until, in fact, the time came for the development of the special aptitudes which had been discovered meanwhile. Nothing can be worse than our present system of regarding those as fools who fail to master one favoured subject; the number of square pegs fitted into round holes will be far fewer when it is abandoned.

An even greater reform will be the abolition of much of the lesson learning and lesson hearing which disgrace our present system. Instead of calling on children to execute tasks in school under skilful and watchful, but as far as possible limited, guidance, much of the time is devoted to hearing lessons learnt under

improper conditions—usually at home after the day's school work is done. Children are never *trained* to make the right use of leisure; they have no proper leisure time in too many instances. A great part of a boy's or girl's school time is wasted in looking on while the work of others is corrected. And the work is done with little or no motive—lesson following lesson in this or that subject simply as a means of getting up the subject; the question, "Why should I do this?" is practically never asked. It is not surprising that we degenerate into machines.

Many of the faults inherent in the present system would soon disappear if the instruction were generally centred around the study of some problem or inquiry —if, in fact, it were largely to hinge upon the work in experimental science: if what may be termed a workshop system, as opposed to the class system, were adopted and each pupil were called on to execute a series of tasks involving the practice in due measure of all the various "arts" contributing to education. This will be regarded by classically trained teachers as the scheme of a madman: but I verily believe it to be the method of the future; that it will be practised in remote days to come when universities and teachers have risen to a right conception of their duty and of the practical needs of life.

The great advantage to be gained by making the work hinge upon the teaching of scientific method is that from the outset the pupil becomes engaged in an inquiry and that his mind is always in contact with facts; he is called on to work with a clearly defined motive, to observe carefully and to reason from observation. As Huxley says, in scientific training it is essential—

that the mind of the scholar should be brought into direct relation with fact, that he should not merely be told a thing but made to see by the use of his own intellect and ability that the thing is so and no otherwise. The great peculiarity of scientific training, that in virtue of which it cannot be replaced by any other discipline whatsoever, is this bringing of the mind directly into contact with fact and practising the intellect in the completest form of induction; that is to say, in drawing conclusions from particular facts made known by immediate observation of nature.

The other studies which enter into ordinary education do not discipline the mind in this way. Mathematical training is almost purely deductive. The mathematician starts with a few simple propositions, the proof of which is so obvious that they are called self-evident and the rest of his work consists of subtle deductions from them. The teaching of languages, at any rate as ordinarily practised, is of the same general nature—authority and tradition furnish the data and the mental operations of the scholar are deductive.

Again, if history be the subject of study, the facts are still taken upon the evidence of tradition and authority. . . .

In all these respects science differs from other educational discipline and *prepares the scholar for common life.* What have we to do in everyday life? Most of the business which demands our attention is matter-of-fact, which needs, in the first place, to be accurately observed or apprehended; in the second, to be interpreted by inductive and deductive reasonings which are altogether similar in their nature to those employed in science. In the one case, as in the other, whatever is taken for granted is so taken at one's own peril; fact and reason are the ultimate arbiters and patience and honesty are the great helpers out of difficulty.

Huxley and other advocates of scientific training have all urged that it must be made practical—and this is generally admitted. But we may go further and assert that it must not only be made practical but also literary: that the proper effect of practical scientific training is not secured unless it be properly developed on the literary—and it may be added, the artistic—side. Thus, in commencing work, the

motive with which the work is done must be distinctly set forth in clear and simple terms, neatly and properly written out. The writing-out causes an understanding of the motive—makes it clear that there is an object in view. Then, as the work is done, the exact way in which it is done is recorded there and then; and drawings are made so that there may be no doubt as to what were the arrangements adopted. Again, in writing out this part of the account, every step taken has to be explained and justified. In the third place, the results obtained are carefully recorded. In the fourth, the deductions to be drawn are pointed out. And in the last, the way in which the observations make it desirable to try some further experiment are fully discussed.

In this way, the scholar is not only led to experiment with a set purpose and to acquire the habits of observing and reasoning logically from observation but each experiment becomes a most valuable lesson in composition and therefore in language—and writing and drawing are practised from day to day; and a good deal of mechanical work must be done in constructing and arranging apparatus.

Teachers will say it is impossible to deal with classes in this way. Of course it is; but teachers should not be allowed to train our sons and daughters in classes: we must insist that they train them as individuals, as units, not as cohorts. The South African war has taught us that we must in future adopt open order fighting—that we must train our soldiers as individuals.

The difficulty is a real one, I admit, and the task hopelessly beyond the capacity of our present race of teachers. But it is useless to say that the thing

cannot be done. Experiments must be made to find out the right way of training boys and girls as individuals—and when these are honestly carried out, ways will soon be found. We don't say that it will be impossible to train our soldiers to exercise intelligence and to act as individuals. We know it has to be done; besides which we know that the Germans have already succeeded. And my own experience has shown me that what I advocate is feasible, given competent teachers; but these are not procurable from the universities and never will be under existing methods. If the public wish for rational education, therefore, they must call on the universities to reform, just as they have recently called on the War Office to reform. The education of the nation, although a far more serious matter than that of the army, has no interest for politicians. And it is easy to see why this should be. Man and all animals have had to fight from the beginning of time and understand what fighting is and like it; education is a modern fancy, which no one understands, and the tendency is to rebel against it. The doctrine of evolution enables us to explain many things; but besides teaching us why we care so little for education, it tells us also that it is now very necessary, if only as a preparation for effective fighting.

If the tables were turned in the manner suggested, it would not be a case of the opposition coming into power and acting in their turn as monopolists but of the introduction of a sound "liberal unionist" policy. And literary studies would in no wise suffer. On the contrary, they would receive their proper share of attention from the outset; they would be cultivated with far more intelligence and by improved

methods; and those who had special literary aptitudes would soon be discovered and would in due time be encouraged to follow their bent. On the other hand, practical studies would have a chance which they do not get at present; their value would be appreciated before the fatal fascination of books had warped the scholar's mind; the inventive powers would be developed, instead of being allowed to atrophy through neglect; eyes would be used and the country would regain its charms; the clerk's desk would no longer be the acme of respectability to so many.

Humanists and realists alike will prove themselves dire enemies of the State, if they do not without further delay take the opportunity that is open to them, the step that is demanded of them, if they do not arrange for the immediate effective union of their forces. Public opinion should insist that this be done.

The schools most in need of drastic reform are those in which our governing classes are educated. Those who have read the account of the *Preparatory Schools for Boys*, forming vol. vi. of the special reports issued by the Board of Education, will have learnt that in these schools the iniquitous and inhuman system prevails of giving up practically the whole time to the teaching of Latin and Greek—this being necessary, as these subjects count before all others in the entrance examinations at the public schools and the competition to enter is a keen one. The importance attached to classics in the Indian Civil Service and the army examinations is also so great that they necessarily secure almost undivided attention. Little wonder that our administrators almost uniformly fail to feel the pulse of the times and show so little desire to govern that our public offices are in the bonds of

red tape and that the bravery of our soldiers is in no wise equalled by their intelligence. In naval education, mathematics is the favoured subject—practical studies, of course, are nowhere. The conditions under which sailors live, it is true, are more practical than those to which soldiers are subjected and to this extent they are better off; but not a few among us feel a sense of great uneasiness as we wonder whether, in the hour of trial, our sailors may not prove to have been ill prepared to face the enormous responsibilities that are cast upon them. The ship of to-day is no longer a ship but a machine shop, yet the "traditions of the service" are such that this is in no way recognised; if it were, a far higher position would be accorded to the naval engineer. Again, prejudice and vested interests prevail. And there is another section of the community in which the neglect of practical studies has specially serious consequences — the medical profession. Very rarely is any proper foundation laid at school for medical studies and the position is rendered worse by the unscientific character of the preliminary medical studies, which can only be described as lesson-learning run mad. The result is, very few medical men enjoy a scientific training; indeed, their training is anti-scientific and clinical practice alone affords them a chance of recovering their mental balance. Little wonder, therefore, that the general practitioner so often proves lacking in skill. Being in the condition described by Lowell's verse, medical men are not likely to cure themselves; indeed they have proved to demonstration that they are not even aware that they are victims of deep-seated disease.

The field of education, it must be admitted, is

everywhere strewn with fossils; as a rule none but fossil types serve as models. It were time that we followed the horticulturist's example and by cross fertilisation and careful cultivation sought to raise new and improved varieties. Surely our children demand this of us?

No moment should be lost in setting our educational house in order. We have not only to keep pace with others but to make up for much lost time; and so much preliminary work has to be done before any effective progress can be made. An understanding must be arrived at as to what are the necessary studies for all and how departures from the general course can be made to suit special cases. The teachers must be trained with utmost care. And the church must no longer be allowed to exercise a preponderating influence.

The writing on the wall is clear enough and is of awful significance. If our statesmen had the faintest conception of the vital importance of the subject, they would commit the preparation of a *national educational programme* forthwith to a small and select body of men who would be likely to deal with the matter in an unselfish and scientific manner—without prejudice and without consideration of vested interests, mindful only of the imperial responsibilities of the nation and of the certainty that unless those responsibilities are met without delay the empire must suffer dismemberment.

IX

AIMS AND METHODS OF SCIENCE TEACHING

I DESIRE to thank Mr. Abbott for his letter in your April issue commenting on my paper in the *London Technical Education Gazette*. It is important that questions such as those about which we are at issue should be brought under notice.

Although I regret that a teacher who is engaged in the good work of endeavouring to help his colleagues to better methods should totally disagree with my remark that "if people learn to weigh things, they will, perhaps, in time learn to weigh opinions," I must confess that I am not in the least surprised. On the contrary, I should have been surprised to find him in agreement with me. The *quantitative sense* has not yet reached the embryonic stage of development among us. Few are sufficiently acquainted with the verb "to weigh" to appreciate its real meaning; very few are able to apply it in all its moods and tenses.

I was not aware that I had wandered into psychology. "Psychology" is a big word but one which is too often synonymous with cant and at best covers a very limited and imperfect doctrine. When, for example, I see questions set seriously for grown-up teachers to answer

such as "How does a child learn to localise sensation on different parts of the surface of his body?" "How is it that a child will, in general, remember best what he thoroughly assimilates and understands?" it seems to me that the sense of the ridiculous must be wanting in the professed psychologist and that we may well be content to work on a more practical plane. If teachers spoke the honest truth of the value to them of present-day psychology, probably most would confess their agreement with the view expressed by the great Clothes-Philosopher when he said, "The 'Enchiridion of Epictetus' I had ever with me, often as my sole companion, and regret to mention that the nourishment it yielded was trifling." At least, all those who had learnt to weigh would fully sympathise with the remark of his editor thereon: "Thou foolish Teufelsdröck! How could it else? Hadst thou not Greek enough to understand thus much? *The end of man is an action and not a thought,* though it were the noblest."

We sadly need a Teufelsdröck at the present day to remind us how little we do to prepare our youth for the field of action, to expose the shams of our ultra-academic system and to move the public to enforce their abandonment. Fortunately he has given us an unsurpassed definition of man, which may well be taken as a guide and as the foundation of a practical psychology. Says Teufelsdröck: "Man is a tool-using animal. Weak in himself and of small stature, he stands on a basis, at most, for the flattest-soled, of some half square foot, insecurely enough; has to straddle out his legs lest the very wind supplant him. Feeblest of bipeds! Three quintals are a crushing load for him; the steer of the meadows tosses him aloft like a waste rag. Nevertheless, he can use tools, can devise tools; with these the

granite mountain melts into light dust before him. He kneads glowing iron as if it were soft paste; seas are his smooth highway, wind and fire his unwearying steeds. Nowhere do we find him without tools; without tools he is nothing, with tools he is all."

How little we bear this in mind—how little we do to teach him to use tools or to understand their use. In schools the time is still given up almost exclusively to the worship of the *Enchiridion*. "The tyranny of the book," as Professor Meiklejohn aptly terms it, still reigns supreme. The psychology which has so long justified such a procedure cannot be worth much and I have no desire to wander into it. I prefer to stick to my balance and to advocate that boys and girls should stand up during a large part of the school day at some kind of work bench, instead of always cramping their chests and intellects at the desk.

As to Nature Study, what is put forward under the name at the present day is, for the most part, sheer pretence—more often than not, empty twaddle, unworthy to be called *study*. Almost invariably, except in the case of the few enthusiasts with innate capabilities, the teaching is of such a character as to merit the reproach addressed to the *Hirt* by the *Jäger*, in the German fable reproduced in your April number:

> "*Ihr scheint, Euren Sohn manches wohl gelehrt zu haben, aber eins habt Ihr vergessen. Warum habt Ihr ihn nicht auch gewöhnt, das Innere zu erforschen bevor er dem Zutrauen sein Herz öffnet? Hätt' er das weiche Mark inwendig geprüft, er würde der täuschenden Rinde nicht getraut haben.*"

"*Das Innere zu erforschen*" should be the essential aim of all true Nature Study. A charming article on Experimental Natural History, by Professor Miall, was published by you in February 1899, which from

beginning to end is a dissertation on the *Erforschungslehre.* "I would have every science lesson take the form of an inquiry," writes Professor Miall, in his concluding paragraph. "Our work is only scientific in spirit when it spring from the desire to know of our own knowledge some definite thing concerning which our curiosity has been moved." I also have been an advocate of "Juvenile Research" for years past; and in the paper referred to, dealing only with the most elementary measurement work, I say, "As far as possible, it must always be some little piece of juvenile research work that is undertaken, some little problem that is worked out."

"Most true is it," says Teufelsdröck, "as a wise man teaches us, that 'Doubt of any sort cannot be removed except by action.'" The aphorism is worthy of consideration by teachers.

Huxley, in his essay on the Study of Biology, addressing the "more or less acute lay and paper philosophers who venture into the region of biological controversy," gives them the advice: "Get a little sound, thorough, elementary instruction in biology." I would venture to urge teachers to eschew psychology until they have had a little sound, thorough, elementary training in quantitative experimental work—and until they know what R-e-s-e-a-r-c-h spells. It must soon be that such knowledge will be exacted of teachers as essential to competence.

X

THE WORKSHOP IN THE SCHOOL

If we are to reform our educational system—or, rather, if we are to have an educational system of some use to us in our everyday affairs—we must bring the workshop into the school. But as I use it this term workshop has both a wide and a restricted meaning: it is not merely the pot bank, the foundry or the rolling-mill; it is no mere factory—state-regulated or otherwise. We all work in some way or other—there are few who are not deserving to be called work-people—we are never really idle—from year's end to year's end, life means one continuous period of work: if the machine stop working, it can never be restarted. Education must not serve commercial ends alone; true education must be a preparation for life as a whole—even true technical education must deal with the individual—with the home and with the leisure time—as well as with the period during which service is rendered to the employer.

In other words, the school must prepare for the world—that greatest of all workshops. At present it does nothing of the kind: it makes no attempt to do so but mainly trains for office employment; desk

work is everywhere being preferred to handiwork. The school is reverting more and more to the purposes of the clerics—the curse of books is upon us: for books *are* a curse when used to train parrots; and such is the use that is too often made of them in these days. Real books—readable books, informing books—are scarcely to be found in schools; sound books are few and far between and their use is in no way properly encouraged.

Several replies have been received to the query which I asked should be put to some among you—as to what were the needs of elementary education in your district. Among them was one from a coal-mine manager, who said—"We want to make the young people less like parrots." I think most of you will agree that my use of the ornithological metaphor is fully warranted.

I am invited to address you on the subject of extending the work of science teaching as part of the ordinary curriculum of the elementary school—but let me say at once I desire to urge something much wider: not merely that science should be taught in the schools but that the schools should be put on a scientific basis. To teach smatterings of science is mere waste of time—to teach scientific method is to move towards salvation: because you cannot be scientific unless you are exact and honest, observant and thoughtful—the parrot has no place in science. To be scientific is not merely to know but to have the power of using the knowledge properly.

To put the school on a scientific basis, its purpose must be carefully thought out; and some understanding having been arrived at, the best way of effecting the

desired purpose with the means at command must be sought for and put into practice without delay.

What then is our object in going to school? To cultivate our intelligence—or as it is often said, our intellectual powers. But the mistake is made of giving too narrow a meaning to the term intellectual powers. A potter in shaping a beautiful vessel makes full use of his intellectual powers none the less because he does the work unconsciously and mainly with his fingers; and the same is true of the skilled artist who paints the design. The potter's intellect is apparently centred in his finger-tips and the arrogant scholar may affect to despise him in consequence and think that he is superior because he works with his brain: but the potter's finger-tips are connected by a marvellous mechanism with his brain—with his intellect; and the scholar is no whit better off—rather is he worse off, because his finger-tips, as a rule, are allowed to atrophy.

The average handicraftsman is in no way inferior to the average scribe or scholar—but quite the contrary: as the man who does *must* be superior to the man who merely knows of or writes or talks about what others do. Raw materials cannot be converted into finished articles without the aid of the practised craftsman: the part the scribe plays in their production is relatively small. But unfortunately the craftsman is not sufficiently considered in our schools—the scribe all but monopolises attention. Or to take another example, the development of the artistic sense is clearly of the utmost importance to the industry of this district. But is this sufficiently taken into account in the schools in the pottery towns? Drawing and brush work, I believe, are encouraged. But the artist, we

know, derives inspiration very largely from Nature. Do your schools bear this sufficiently in mind and seek to develop in your children some power of appreciating the beauties of Nature? Have they before them objects of beauty such as would serve to correct the impression made on them by dull surroundings? Is anything done to educate their powers of imagination? Much could be done by leading them to study and grasp the meaning of some of the wondrous changes going on unperceived under their very eyes. Books cannot do this. Mere information lessons will not suffice.

Again, is not the right use of coal—economy of fuel—a subject deserving most careful attention in the Staffordshire district—but how many leave school with any understanding of such matters? How many of us here to-night can sit in front of a fire and call up any mental picture of the play of forces it embodies? Such being our ignorance, it is in no way surprising that we are so absolutely improvident in our use of coal that we never for one minute think of the storm of execration we shall reap in consequence from future generations. Our absolute selfishness in such matters rarely strikes any one.

Your iron-works may appear to be dirty, untidy places: but in reality they are full of wondrous machinery; those who help in making and shaping the metal have strange and beautiful phenomena brought coustantly before their eyes: but how many see anything—how many can enter in imagination into the marvellous changes that are going on before them or in any way realise how full of life, as it were, is the hot iron bar? Surely, if the schools taught how some of these things may be understood, the daily toil would

appear far less irksome and the work might be more skilfully and reverently done.

I believe the question of glazes has excited some interest in this district of late—would it ever have assumed the acute form it did if those who worked with them had done so thoughtfully?

One last illustration—if we turn to the domestic side of our life, how many among us understand ourselves? Just consider how little interest we take in ourselves; how little we do towards studying even our own comfort. The vast majority never ask whether they may not themselves be to blame for the state of discomfort in which they live. Surely we may well leave it an open question whether Alfred burnt the cakes or not—and turn to the consideration of the best means of preventing our own fingers from being burnt.

If we did so, we should perhaps realise that the power of imagination, insight, is almost crushed out of us in these days—and that instead of glorying in the wonders around us we are reduced to wiling away our time by reading rubbish utterly unworthy of attention and from which no useful impulse or inspiration whatever can be gained. "But why labour such a point," you may say—"as practical Englishmen we have little to do with imagination." But is this so? If we lack imagination, we must lack imaginative power; if we lack imaginative power we cannot progress. There is an interesting article in the *Nineteenth Century Magazine* for Dec. 1901 by Sir Wemyss Reid, entitled "A Message from America"—an account of his experience there in November last. Sir Wemyss Reid writes—"Our best friends on the other side of the Atlantic make no secret of their conviction that Great Britain, compared with

the United States, has fallen into a state of lethargy which, unless it be speedily shaken off, must enable the latter country to leave it hopelessly behind in the race for commercial and industrial prosperity." To express my own view, four years ago I returned from the States, after going twice across the Continent from east to west, with the settled conviction that unless we could change our tactics it would be well for us soon to petition to be hauled bodily across the herring-pond. Few people in this country seem to appreciate the force latent in America and the American people. We talk of German competition but it always seems to me that it does not deserve a moment's consideration in comparison with American.

A good illustration of the way in which the play of imagination may be stifled by usage has just come to my notice. You have all heard of Klondyke in connection with the wonderful discoveries of gold made there a few years back. When the news got abroad, experienced gold-miners flocked there from all parts of America and men of all sorts as well. Who have been the successful men in the long-run? A friend—a distinguished geologist and mineralogist—who has just been there tells me: not the miners. As you know, it is a region where eternal frost prevails. The miners found that the methods which they had been accustomed to use could not be successfully applied but like lawyers they were bent on following established precedents—and as in the case of the Oxford don: what they didn't know wasn't knowledge. The butchers, the bakers, the candlestick-makers, on the other hand, had no rooted prejudices in their minds to clog their imagination: all methods of mining were alike to them and it was as easy to think out new ones as to learn the old

ones. So it has occurred to them to carry steam pipes down and just thaw the ground: and they get out the gold easily.

In other words—it is not mere knowledge that tells but the use we make of it; it is the attitude we adopt towards the facts that determines our success. We must follow the example set in the Klondyke but instead of thawing the ground we must use high-pressure steam in blowing out of their seats the teachers who will not march with the times.

In like manner we must be prepared to introduce new methods into education. We must seek to bring plastic minds to the solution of its problems. And teachers must seek to get out of the grooves in which they have been running and to enter upon new tracks—for it is not only that we have to teach new subjects: we must also revise our methods of teaching the old ones. Take history for example: this is generally considered to be a subject of importance—and so it is if properly studied; if what has happened in the past be used as a means of forming sound opinions to guide our present conduct. But to this end we need to treat the subject far more generally—to consider what has happened in the world at large and not merely what has gone on in our own little island. And we have to bear in mind that history prior to the introduction of steam and electricity is something very different from history in the subsequent period; discoveries of workers in science have altogether changed the conditions under which we live. Many new factors have been introduced into our civilisation and we are now forced to reconsider many of the lessons taught by the remoter past.

We must also remember that our whole tone of

thought has been changed during the latter part of last century and by one man: Charles Darwin. No intelligent person in these days should be without some knowledge of the doctrine of evolution—of the struggle for existence which is going on throughout the living world. Fortunately, Mr. Murray has just come to our aid by publishing a shilling edition of the *Origin of Species* well printed on good paper and has thereby done the greatest service to the cause of education. It is a difficult book to read and only part of it can be understood by ordinary readers; but the attempt should none the less be made to master its main principles and to note the wonderful patience and care with which its results were arrived at.

We must now consider how the Workshop can be introduced into the school. Really, there should be several but in practice, for some time to come, we must be satisfied with one—but in building new schools, the present form of design should be altered and less class room and more workshop accommodation should be provided. In some schools, provision is already made under the guise of a laboratory—a latinised form of the word workshop which ought to be got rid of, both because it is not understood by the general public and because the kind of instruction given in the laboratory has too often been of an artificial type such as we do not want in schools. The great mistake hitherto made in schools, in fact, has been that so-called science has been taught in them much in the way in which it is taught in the professional schools of science. I want to abolish the specific term science altogether from school work: all the school work must be put on a scientific basis, as

I have already said; and every subject must be taught in a scientific manner.

What we need to recognise is that there are three *necessary* subjects of instruction—experimental work, literary work and manual work.

At present we confine the child to the desk during almost the whole of the school period and lesson after lesson is given by the teacher: the child for the most part merely imbibes information either from the teacher or the book. The great object is to fill its memory box. I want to see the workshop method introduced —*i.e.* specific tasks set in the form of *problems* which each child is to work out experimentally, the teacher merely acting as foreman. When experimental work is done in this way, it tends to develop habits of independence, children become observant and thoughtful, their imagination is called into play; if properly led they become exact and honest workers; instead of becoming parrots, they learn to think and act for themselves. You cannot give the training in any other way—as you have to develop the practical side of the child to do all this.

It is to the extreme importance of this kind of work that I desire to draw the attention of teachers. I know it is very different from that to which they are accustomed—and that it is difficult because the method is unfamiliar; but I would earnestly beg of them to attempt it; I can assure them that as they gain experience they will find it grow upon them and their own powers of undertaking it ever on the increase.

XI

SCIENCE TEACHING IN SCHOOLS IN AGRICULTURAL DISTRICTS

THE subject we are to consider together is beset with difficulties which can be overcome only slowly as the main principles are made clear on which such teaching must be based; in no case, probably, is the difficulty greater than in the present, when we are seeking to arrive at some agreement as to the course of instruction most suitable for an agricultural community.

We are all aware of the vast importance of agriculture to our country and of the depressed condition of the industry; and no task can be more congenial to Englishmen than to contribute, in however slight a degree, to the amelioration of a condition of affairs which it is impossible to regard as irremediable, however far off we may be from the discovery of an effective means of escape from our troubles. The question is—in what direction are we to look for help? Many of us can see no evidence that it could ever come from the imposition of protective duties or the introduction of bimetallism, neither of which can be expected to put an end to that over-competition from which the civilised world generally is suffering, owing to the extraordinarily rapid rate at which population

is increasing and the consequent difficulty of finding remunerative occupations, as well as to the marvellous improvement in our means of communication. There appears, in fact, to be but one way open to us, if we are to win our fair share (we have no right to more) of reward for our toil—that one way being to increase our intelligence and thus to fit ourselves more fully to bear an honourable part in the struggle: in fact, to take to heart the lessons of that same "science" the successful application of which in the service of the world has been so largely the cause of our troubles.

In war nowadays we no longer fight with mere spears and darts and unprotected; and so it is in industry: we must be both highly trained and fully equipped, as well as effectively organised, if we are to succeed. Surely no industry offers problems of greater diversity, complexity and uncertainty than does agriculture! Those who act as its leaders need therefore to be highly intelligent; and as success is so much a question of circumstances outside the immediate control of the agriculturist, it is especially important that agricultural workers generally should be thoroughly organised so as to work in co-operation.

But is all this sufficiently recognised? Is not agriculture naturally and necessarily an eminently conservative industry; and is there not consequently a great need of some "force" which will make us more ready to consider new possibilities?

If we cannot any longer sell wheat at a profit, are we therefore to allow land to go out of cultivation because it will not bear other crops? Surely not. We must discover ways of converting wheat into more saleable products if we cannot discover ways of making such land available for other purposes. While butter,

eggs, meat, fruit, onions and many other perishable articles of many million pounds' value are annually imported, we have little right to complain of anything but our own inability to fight the battle of life—such, at least, is the impression gained by many outsiders like myself. And seasons such as the present and that of 1893 should give rise to thankfulness rather than to grumbling. The world depends on solar energy and in raising crops we are forced to use this as we receive it, not being in a position to store it; but water, which is also a prime necessary of the farmer, can be stored. Surely more should be done to avert the effects of drought and to utilise the glorious sunshine of which so ample a share has been at our disposal during the two seasons referred to. Of course I am aware, as every one must be who has a garden and has noted the difference between natural and artificial watering, that the atmospheric conditions of a dry season are peculiar and not always favourable to growth even when water is freely supplied; but there is no doubt that much might be done by irrigation: there is a wide field open for those who will experiment on the effect of artificial manuring and irrigation combined, the value of which is often strikingly manifest in pot culture.

All, indeed, must admit that in order to restore a full measure of prosperity to the agricultural community there must be many changes—greater love for the country must become manifest; the desire to migrate into the big towns must in some way be counteracted; habits of thrift and providence must be developed far more widely; that overbearing confidence in himself which distinguishes the Englishman, which in times gone by has enabled him to accomplish so much, must

be tempered by greater willingness to ask for and receive advice and to act in co-operation with others; and while in no way ceasing to be practical we must learn also to appreciate the great value of theory.

Japan has recently given the world one of the greatest object-lessons ever put before it and has shown us what can be done by intelligent study and application of modern methods. In the course of a quarter of a century, by careful organisation, she has raised herself to a very high rank among the powers: if we could but bring ourselves to follow her example and show similar receptivity, it cannot be doubted that necessary changes would be rapidly made, instead—as is too often our custom—of their being resisted until inevitable.

You may ask, Why do I refer to all these questions in an address on science teaching? Because it is the function of the teacher at school to lay the foundations of character; because it is upon the teacher that the responsibility must ever rest of giving the most effective preparation for the work of life; and because it is mainly to the introduction of *more scientific methods of teaching* into our schools that we must look for improvements in the intellectual status of the agricultural community. The old methods have clearly failed; we have, therefore, the right to push them aside and try new ones.

Indeed, it is generally admitted that our educational system is in an extremely backward condition: the technical education movement of our time, which has led to the erection of colleges such as this, is but the outward expression of the feeling that something must be done to improve our position. Technical colleges, however, will never exercise their proper influence

until the preliminary training of those who study in them is conducted on more rational lines. But to what extent is the teacher at present prepared or, if willing, in the position, to meet the requirements of the time?

Unfortunately, those who have hitherto had the control of education have been for the most part in the condition of men trained only to use bows and arrows set to fight an enemy fully armed with modern weapons of the use and effectiveness of which they have no understanding. Educated mainly on classical lines, they have been practically ignorant of the workings of the great world of Nature and their methods have been too exclusively introspective—too bookish. How can such men act as our leaders and guides when the fight is against Nature?

It is clear that if we are to recover our prosperity there must be an absolute revolution against prevailing practices. We must give up talking nonsense about the supreme value of classical training and must recognise that, however good, such training must ever lead to a one-sided development of the mind. And not only so—although of the greatest value in its place and when not allowed too exclusively to occupy the attention of the pupil—in the opinion of many, unless carried far enough, the educational and disciplinary effect of "classical" studies is very slight, both absolutely and in comparison with that afforded by studies of natural objects and phenomena, when these latter studies are properly conducted so as to afford training in method and not mere knowledge of facts. I make this reference to the subject, not because teachers in elementary schools are in any way concerned with classical studies but because the

methods which they have hitherto been required to adopt are the direct outcome of the classical system—because the inspectors under whom they work are far too exclusively in sympathy with it alone.

Without delay, we must enforce the introduction of scientific method into schools and the consequent abolition of mere lesson learning. In the ideal school of the future I picture the teacher no longer hearing lessons but quietly moving about among the pupils, all earnestly at work and deeply interested, aiding each to accomplish the allotted task as far as possible alone, caring little to ascertain what they know but making every effort to lead each to *do* something. The picture is not altogether an ideal one, far as it may be removed from that now to be met with in our schools. In our college courses such a method is actually adopted.

The mechanical arts of reading, writing and working elementary problems in arithmetic must necessarily occupy the first place and must be taught mechanically, although arithmetic may easily and with great advantage be taught practically—indeed, it must be in the future. But afterwards, next in order, must come effective training in the nature and use of scientific method—the equivalent of drill and discipline in the case of an army. Spelling, grammar, history, geography and similar subjects may safely be relegated to very secondary positions in the programme. We must ever seek to teach not mere facts but above all things the use of facts and how the knowledge of new facts may be gained and use made of them. Our aim must be to make our pupils exact and therefore truthful, observant, thoughtful and dextrous. We must lay the most solid foundation possible for future self-education and do all in our power to encourage the growth of the

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spirit of inquiry or research. *For work of this kind we may and must claim the first place.*

When the object in view is clearly grasped, methods and subjects will almost spontaneously suggest themselves to the competent teacher.

But be it before all things remembered that it will be important not to attempt too much; whatever is done must be well and thoroughly done, so as to secure the full disciplinary effect. It is useless to give a lesson on this and another on that subject; almost useless to *give lessons* at all. The same exercise, only sufficiently varied to make it interesting, must be repeated over and over again until the subject is mastered. It must also not be forgotten that we vary greatly in disposition and capacity, that it is impossible to treat all alike during their school career; although up to a certain point the attempt must be made to train all alike to do certain things knowledge of which is of primary importance to every individual.

It is in the hope of contributing something towards the projection of a satisfactory course of studies in your schools that I am addressing you this evening. I do most certainly desire to stir up strife and make people generally dissatisfied with the existing condition of affairs educational, feeling that without help from the general public we shall make but little progress. Yet, on the other hand, I have no belief in criticism which is merely destructive and have therefore always done my best during the past dozen years or more to criticise constructively.

As to the course of the future, it is to be hoped that in a few years' time we shall have removed all specific "science" subjects from the programme at least of elementary schools and shall have substituted

one common subject—that of "Natural Knowledge" —to include all that is necessary of botany, chemistry, physics, physiology, etc., such scheme being made sufficiently elastic to permit of due consideration being given to the special wants of particular sections of the community. We are far too much in the habit of using the word "science" in a restricted sense, forgetting that all exact co-ordinated knowledge is science —that all teaching in schools should be *scientific.*

As soon as any one specific subject is taught, there is at once a tendency to treat it from the specialist's point of view and to defer to the specialist in drafting the programme; consequently, educational requirements are too often disregarded. This perhaps more than anything else has rendered much of the science teaching in schools entirely unsatisfactory.

It is very difficult to decide what should be the limits of each subject and the proportions they should bear to each other: so much will ever depend on the intellectual capacity of the scholars, the time over which the course extends, the means you have at your disposal—last, but not least, whether you regard such teaching as disciplinary or from a more purely utilitarian standpoint.

I should say, begin as early and continue as long as possible, so as to secure as much time as possible for such work; and regard the instruction entirely from the disciplinary point of view while you base it on utilitarian considerations. You *must* begin very early, otherwise you will find that the deadening effect of ordinary lesson-learning will materially check progress and that other interests will have been acquired and the natural curiosity of the young child will have begun to die out. But it is needless to consider how

much can be done, any more than it is to consider how much food shall be given to a child during a certain number of years. The inspector of the future will be satisfied with evidence that you have taught regularly and rationally during the year and will not exact proof of a certain stage of mental development having been attained during the year any more than he requires a particular stage of physical development to be reached. The essence of your method must be that practically everything is done by the scholars themselves. We all know how easily we forget most things which are told to us or which we read about; how rarely we forget what we have ourselves done. I believe that even the best of object lessons are of very little use except in the case of those who have learnt to help themselves.

XII

TRAINING IN SCIENTIFIC METHOD AS A CENTRAL MOTIVE IN ELEMENTARY SCHOOLS

AT present there is neither a central subject nor a central motive in the course of training given in our schools, whatever their grade. The need of co-ordinating and correlating studies is scarcely thought of, each subject being taught separately, so that much time is wasted and many opportunities are lost.

The proposition I desire to submit to-day is that the central idea—the central motive—in elementary schools should be to give training in *scientific method.*

Some, perhaps many, will be inclined at once to hold up their hands in horror. To teach *science* at all, they will say, is unnecessary; to urge that it should be the central subject is preposterous! But I would ask such to pause—to consider what the term I use implies. And perhaps they will be relieved when I say that I am not here to advocate the introduction into the school of *science* in the ordinary acceptation of the term. For years, in fact, I have objected to the teaching of specific branches of science in schools and have contended for something more general—that training should be given which will

tend to develop what are becoming known as scientific habits of mind: *i.e.* thoughtfulness and power of seeing; accuracy of thought, of word and of deed. What I have to say has equal application to all the subjects of instruction—the old as well as the new.

It is unfortunate that the words science and scientific are but disguised Latin words which scarcely convey any clear meaning to most people, as they refer to something unfamiliar—to something which many are inclined to regard in the light of a luxury. It is perhaps easier to understand them if we translate the words into German and then back into Anglo-Saxon. The German equivalent of our word science is *Wissenschaft—the business of knowing.* To be scientific is to be knowing or canny, in the best and highest and fullest sense of the term: the knowing man being one who *can*—who has the power of doing, of producing as well as of holding. Surely, no one can object to become scientific, if such be the meaning of the term; all will wish to be scientifically inclined.

Now, although it is universally held that the great object of school training should be to develop aptitude, the complaint is universal that we fail to accomplish our object. In some way or other, the track is departed from and we are off the rails; we are not securing what we feel and know is wanted.

Absence of imaginative power seems to be at the root of our difficulties; and consequently we are both apathetic and prejudiced. Perhaps nothing is more important at the present time than that teachers should cultivate their powers of imagination. To get back upon the rails, we must treat the problem scientifically—with true knowingness. We must consider most carefully what is the material to be

dealt with and what we are to aim at; and then see how our object can be gained.

The material to be dealt with is an active young animal whose healthy natural desire is to rove about and be inquisitive about things generally; to dissect and to get at the inside of things; a young animal full of latent ability and with strongly marked practical tendencies. Instead of developing his natural instincts, his imaginative power and his individuality, we glue him to a desk and cram him with mere facts—mainly from books. We practically shut him off from the world outside and we scarcely allow him to handle anything: the instinct to experiment, which is so highly developed in children, is almost if not altogether disregarded. There is neither common-sense nor morality in such a system!

The greatest mistake of all that we make is that we cultivate only one set of the pupil's faculties even when the teaching is really good—and that not the most useful to the majority. The system is in all its essentials a literary system, not a practical system. Training intended at one time for a certain very limited section of the community has been extended in course of time to the whole of the community; and naturally the results are unsatisfactory—in many cases deplorable.

I firmly believe that if we are ever to make schools in rural districts a success, we must carry on the school for a great part of the time, not within four brick walls, *but out of doors in touch with Nature.*[1]

[1] To put education in rural schools on a sound basis, it will be necessary, I am sure, to adopt a course such as I advocated in a letter to the *Times*, on February 10, 1900, viz., to appoint a few competent men to co-operate with the teachers and assist them in working out satisfactory schemes of instruction. Each such adviser should have

A certain considerable part of the time must necessarily be taken up in doing routine systematic work and in working up the observations gathered out of doors: indeed, by carrying on such work in the school we are but preparing scholars to do routine work when they go out into the world. But we must recognise that human responsibilities cannot be successfully met unless we are prepared to cope with the complex conditions under which we live, which can only be if we have gained some insight into their character at school.

The teacher of the future must be guide, philosopher and friend to the taught—not a mere trainer of parrots. And the work of the teacher must be held in deepest respect. But to this end, he must cut himself adrift from codes and become a self-acting, reasoning being, prepared to see and use his opportunities—not a mere automaton wound up once for all at a training college.

We are no longer satisfied to teach children merely to read, write and do sums. We recognise that every scheme is incomplete which limits instruction in principle to those three subjects. But we are still far from agreeing what a full scheme of studies should comprise. Fortunately, we are at last beginning to admit that besides learning to write, if possible, all must learn to draw; and that fingers must be cultivated and accustomed to use tools of various kinds. The doctrine that man is a tool-using animal was taught long ago by a prince among literary men,

charge of a particular district. We must help the teachers now in the schools to improve their methods, as well as train their successors. When the new Act comes into force, it will be easy for county authorities to institute experiments such as I suggest.

Carlyle, but its full significance is not yet recognised. Only this year, instruction in manual training has been made a necessary part of the teacher's course and I believe that teachers in training at the universities are still unable to obtain such instruction: the literary men have not yet appreciated the force of the teaching of one of the most distinguished of their craft.

We are so accustomed to our eyes, that we fail to recognise that eyes must be taught if they are to see properly: that they need training if they are to see with greater intelligence than a photographic plate; that they need to be trained to interpret not only written or printed signs but also the signs in the great book of Nature around us.

And although we value experience, we scarcely recognise that the habit of asking questions and some skill in obtaining answers to such questions by means of experiments—the art of gaining experience, in fact—is one which needs the most careful cultivation if it is to be carried to any degree of perfection.

Unless we can enlarge our conception of the school curriculum, we shall make no progress. Unless we can admit that it is necessary to give all the faculties an even chance of developing, we shall do little good. To this end, we need, as I have said, to be scientific—to be really knowing.

The chief fault in our present system is that it involves too much lesson-learning. Too many subject *lessons* are given—subject *studies* should be substituted, just as object *studies* are now advocated rather than object *lessons*. The conventional object lesson, in fact, is a model of what should be avoided.

How is such a programme as I have suggested to

be carried out? In the first place, it involves treating the child as something more than an automaton—it involves putting the child on an independent footing and treating it as capable of exercising some measure of independence. It must not be told: "Learn this, learn that,"—but "try to execute this task, try to solve this problem, look up information on this or that topic and so learn how to use books usefully." Sympathy must be engendered between teacher and taught, so that there may be a constant interchange of views.

We must lead children to see that they are not engaged in learning isolated lessons but working to a desirable end—lead them, in fact, to take a real interest in their school work and acquire the habit of working without compulsion. It must no longer be a reproach to us that, as Thring puts it—"The school-boy alone is turned loose into the working world without the smallest idea of what he is about or how to work." Every teacher should study the little volume of *Addresses* by Thring (London: T. Fisher Unwin), from which this is a quotation.

I know that what I am urging can be done and that the capable teacher will find great joy in doing it—but exactly how it can be best done, I will not now venture to say. My object to-day is to ask that some of you will attempt the task—that freedom may be given you to attempt it. In fact, one of the very first things to be done under the new Education Act will be, I imagine, to provide that teachers here and there are set to investigate—to find out what can be done to improve the methods.

I have said that much of the work must be done out of doors. It should, in fact, be the aim in a rural

district to develop among the pupils of a school an accurate and, therefore, a scientific knowledge of the district and of all that goes on in it, in order that they may be led to use their eyes and behave as intelligent beings when they go out into the world. They should explore the district thoroughly, be conversant with its rocks, its plants and its animals. They should be familiar with all the features of the country close at hand and should be able to recognise them on the Survey map, not forgetting the geological map. The character of a district to be visited should be worked out in detail on the maps and then verified by inspection. Outline tracings might be made from the 6-inch survey maps and all the details filled in from observation, colours being used to bring out differences in soil, crops, etc. The map-making would lead up to all sorts of measurement work, including simple surveying; and the training in mathematics given in the school might be developed to any desired extent in carrying out such work. Of course, the children would be taught *to make maps before any maps were consulted*—by drawing plans to scale of the school-room and its furniture. Drawing and painting would be practised in order to illustrate the account of the outing—some of the seniors might even take photographs—and in writing out the account, literary powers might be developed: grammar, spelling and composition might all be taught incidentally.

The rocks of the district might be collected and studied in school, thus giving rise to experimental work—in the course of which they would learn to measure and weigh—if such work had not been already introduced in other ways. Parenthetically I may refer teachers who need help in devising a course

of experimental work to the scheme sketched by me for teachers in training colleges, published by the Education Department. The influence of situation, etc., on trees and plants might be brought out by mapping their distribution and seeing how this was affected by various factors. And experimental inquiries should be systematically carried on in the school garden. All sorts of records might be kept—of weather conditions; of the time of first appearance and of disappearance of various plants, etc.; of the number and weight of the eggs obtained from and the cost of the food supplied to poultry. Opportunity should also be found for wood and iron work; and gradually it would be discovered which boys had the knack of using their hands. Under such a system, the special aptitudes of the various scholars would infallibly be discovered. Seeing eyes would be cultivated; a lively interest would be excited in surroundings; and the power of putting questions and obtaining answers by observation, comparison and simple experiments would be acquired.

But the greatest advantage such training would have is that it would gradually accustom the pupils to be self-helpful—and that they would learn to take an interest in things about them. The habit of inquiry having been once gained, a desire to go further would be created in the minds of all but the unintelligent.

Let me advocate one other thing—that the art of reading be cultivated. In these days the cost of books should be no difficulty and it is to be hoped that at no distant date publishers will print good cheap books in readable type. Children learn to read with surprising facility and will read eagerly, if the example be once set them and due opportunity

provided. I hope, indeed, that in the near future it will be a common sight in schools often to find the children all earnestly engaged in reading healthy books —at present no school teaches reading: the tendency to read rubbish now so manifest is, therefore, not surprising.

The doctrine I have advocated may appear revolutionary but there is really nothing novel in it. No less an authority than Thring—one of the greatest of public school masters—advises: "Let lesson books and lesson hearing depart and reading books and teachers come in. Exit paper, enter life." And in addressing teachers on the need of a reform in our methods, and asking them what was to be done, he said: "I answer boldly: First break down the knowledge idol. Smash up the idolatry of knowledge. Frankly and fairly admit that the majority of mankind cannot get much knowledge; and that any attempt to make them get it is a manufacture of stupidity, a downward education. It can't be done." Let us recognise that—"It can't be done." And let us seek to form an ideal which will guide us to what can be done.

It will be desirable that I should add a few words as regards the specific teaching of "science" in elementary schools. First, as to appliances. There is a very wrong idea abroad that very special and expensive accommodation must be provided. This is not the case. There must, however, be space in which the work can be done; there must be a workshop—don't call it a laboratory: this should be fitted *as a workshop, simply*. And there should be no lecture or class room: all the work should be done at the work bench. The tools need not be many but must be good of their kind—and much should be done with home-made apparatus. Measuring appli-

ances come first and foremost: they are indispensable. All true science is based on exact measurement—the introduction of measurement work is the distinguishing feature of modern improvements in our methods of teaching "science"; the value of "science" as a school subject is largely due to the fact that it necessitates the introduction of measurement work into the course. A great variety of simple problems bearing on everyday matters can be solved by means of simple measurements.

But the great object of the teacher of "science" should be to teach *the art of experimenting*—the meaning and use of an experiment. Therefore, the motive with which each experiment is made must be clearly understood; the best way of making it must be thought out; it must be made deliberately; the result must be carefully noted. Finally, the bearing of the result—the extent to which it affords an answer to the question asked—must be considered; if the answer be not satisfactory or complete, other experiments must be devised.

Not a few of us think that the art of experimenting is the art which it is most necessary that the British nation should acquire—that if we knew how to experiment, if we were willing to experiment, we should soon find satisfactory solutions to the problems which confront us.

Very few teachers have any proper conception of the nature of an experiment. To show, for example that a substance burns in oxygen in a brilliant manner, that when A and B are mixed something happens, is merely to give an object lesson or demonstration; it is not experimenting. However valuable and helpful in teaching such practical demonstrations may

be, they do not constitute experimental teaching. To experiment, according to the dictionary, is to search out by trial. The essential first step in an experiment is to have a clear conception of the nature of the quest in which it is proposed to engage. When the motive is clear, some clue must be sought for and followed up. In fact, I am in the habit of advising students who are learning to become experimentalists to put aside all ordinary text-books and to read detective stories and books such as Baden-Powell's shilling *Aids to Scouting;* and I ask them to picture such a change as the rusting of iron, for example, as comparable with a murder and the discovery and isolation of the substance which causes it as comparable with the tracking down, conviction and final execution of a murderer.

I would advise every teacher to read very carefully and ponder over "The Ship that Found Herself," in Rudyard Kipling's collection of stories published under the title of *The Day's Work.* The wonderful way in which Kipling pictures and calls to mind what goes on in every part of the ship as she breasts the storm may help the teacher to realise what his attitude should be towards the problem he seeks to solve; may help him to find the right way of cultivating the seeing eye in his pupils; may help him to acquire some measure of independence, some imaginative power.

Every teacher should possess Darwin's *Origin of Species*—now that an excellently-printed copy costs only one shilling—and should seek to understand its method. The formal literature advocated in the past by the Board of Education and the Master of Method may safely be put on the shelf, if books such as those I have mentioned are studied.

In teaching children to experiment, a teacher must exercise extraordinary self-restraint in withholding information: however slowly the argument may develop, it *must be allowed* to develop solely on the basis of the facts established in the course of the inquiry taken in conjunction with common knowledge. Teachers are not trained at present to work in such a spirit—but more's the pity, more's the shame! To make our teaching something else than parrot training, the teacher must be imbued with the spirit of the discoverer. A teacher who tries to force himself to work from such a point of view may experience great difficulty at first—but if he but persevere, he will sooner or later succeed and what will astonish him most will be the growth of his own power.

It should be unnecessary to say that books should not be used in teaching the elements of experimental science in schools—each scholar should gradually write his or her own book: in such clear and simple language moreover that the home circle could read it with understanding and know why everything had been done and what had been discovered. A multitude of text-books are being written at the present day by persons with no qualification whatever for the office; such books are being used with most disastrous results. Most of the Nature Study pamphlets which are being circulated introduce an entirely false point of view into the teaching. It cannot be too strongly insisted that the object in view—the training of the faculties —requires, not that information should be *imparted*, but that information should be *gained* by personal observation and experimenting. We shall get no further by merely talking about things.

XIII

DOMESTIC SCIENCE IN ELEMENTARY SCHOOLS

In a noteworthy article published in the *Contemporary Review* in 1870, on "The School Boards: What they can Do and what they may Do," written before the first election took place, Huxley—who, it will be remembered, was a member of the School Board for London during the first year of its existence—pointed out what in his judgment ought to be the nature and scope of the education which a School Board should endeavour to give to every child under its influence. It should, he said, include at least three kinds of instruction and of discipline. First in order came physical training and drill as part of the regular business of the school; then, in the case of girls especially, instruction in the elements of household work and of domestic economy; and last, but not least, acquaintance with the elementary laws of conduct and training of the affections, so that all might learn to love with all their hearts that conduct which tends to the attainment of the highest good for themselves and their fellow-men and to hate with all their hearts that opposite course of action which is fraught with evil.

Great as is the work already accomplished by School Boards, this programme is yet far from being realised; indeed, it is to be feared that the introduction of mechanical methods of dealing with masses—perhaps inevitable at the outset of so vast a social change—has led us to overlook its existence almost entirely.

Huxley advised that teaching in the elements of household work and of domestic economy should be provided for girls especially—"in the first place for their own sakes and in the second for that of their future employers." The words he used in support of his contention are worth quoting:

"Every one who knows anything of the life of the English poor is aware of the misery and waste caused by their want of knowledge of domestic economy and by their lack of habits of frugality and method. I suppose it is no exaggeration to say that a poor Frenchwoman would make the money which the wife of a poor Englishman spends in food go twice as far, and at the same time turn out twice as palatable a dinner. Why Englishmen, who are so notoriously fond of good living, should be so helplessly incompetent in the art of cookery is one of the great mysteries of nature; but from the varied abominations of the railway refreshment rooms to the monotonous dinners of the poor, English feeding is either wasteful or nasty, or both. And as to domestic service, the groans of the housewives of England ascend to heaven! In five cases out of six the girl who takes a place has to be trained by her mistress in the first rudiments of decency and order; and it is a mercy if she does not turn up her nose at anything like the mention of an honest and proper economy. Thousands of young girls

are said to starve or worse yearly in London; and at the same time thousands of mistresses of households are ready to pay high wages for a decent housemaid or cook or a fair workwoman and can by no means get what they want. Surely, if the elementary schools are worth anything, they may put an end to a state of things which is demoralising the poor, while it is wasting the lives of those better off in small worries and annoyances."

The lapse of a quarter of a century leaves us much as we were when Huxley spoke and many go so far as to say that School Boards have made our position worse in many respects by favouring unpractical methods of training. Huxley's picture may safely be said to have been under rather than over painted: all classes—not only those specifically referred to by him—are still hampered by the general absence of knowledge of true domestic economy. Just consider how ignorant we all are of almost everything concerning us in daily life. The cook in the kitchen has no eyes—her fire is scarcely ever proportioned to the work it has to do and coals are wasted to a terrible extent; she scarcely knows when water really boils and consequently she has no clear idea of the difference between boiling and what the cookery books call simmering, so that if she cook an egg properly it is by a lucky accident; she uses the same saucepan over a fire and over a gas-burner, never realising how important it is to have such vessels clean outside as well as inside; she rarely weighs or measures anything, therefore the puddings are seldom twice alike and her coffee is more often than not undrinkable. But her mistress is even more ignorant and cannot instruct her to do better; she has not the faintest

understanding what food is, of what use it is to us or in what respects different foods differ—consequently our whole system of feeding is purely empirical: and it is not only wasteful but in many cases great harm is done by irrational or over feeding. The harm done to infants through thoughtless and improper feeding is incalculable. Do not suppose, however, that I think the women alone are in fault. The ignorance of the master of the house is usually equal to that of the mistress and the cook combined, so that even if he have the time, he has never the inclination to help them out of their difficulties. How many men have any understanding of sanitary matters and are able to judge whether their house is in reasonable sanitary repair or to exercise intelligent supervision of any workmen who are called into the house? How many understand what happens when coal burns and why smoke is produced? The consequence of this ignorance is that fog afflicts us out of doors during the winter months and mentally during the whole year. Clearly the only way of getting rid of the fog difficulty is to raise the intelligence of the householder—the legislation asked for by many will not do it.

Do I exaggerate our ignorance of what is going on around us, our inability to understand, our apathy towards our surroundings? I am in the habit of watching others and the experiences I have acquired as the father of a large family and as a householder teaches me that although we manage to get on with more or less of comfort, there is great waste of energy and material and in many cases much suffering—all arising, not so much from our ignorance, as from our thoughtlessness and eyelessness.

The domestic economy—or *domestic science*, as we

desire to call it—in which, therefore, all should be more or less instructed, is something wider than is indicated by Huxley's mere words, though scarcely, I believe, than was in his mind; something wider than the conventional domestic economy recognised and supported by County Councils and School Boards, which usually comprises mere elementary technical instruction in cookery, sewing and washing. Not that I would disparage these—on the contrary; but something much more fundamental and even far less technical is needed by way of preparation in order that really sound training may be given later on in the very subjects which are of primary importance. Domestic science, moreover, as I have already implied, is as much a subject for boys as for girls—for men as for women. This is far too rarely recognised; and not only so but it is beyond question, in the opinion of many, that we are neglecting to give the truly technical education that will assist to make home life happy and the labour of all workers efficient; that by teaching a smattering of everything we get thoroughness in nothing.

Why is it, may be asked, that while we are so solicitous in our care of bodily health, we pay so little *serious* attention to mental health; that so little has been done towards establishing in the public mind any proper conception as to what constitutes mental health?

When people are killed by bad drains we are moved at once to take notice of the evil; but mental injuries conditioned by defective education, far more serious probably in the aggregate than those affecting our bodily health, are but rarely correctly diagnosed. If they were, we should not continue to allow the

intellects of our children to be "stunted by procrustean attempts to teach them all the same accomplishments, to the neglect most often of any sound practical training of their faculties." In these matters we are still living in an age of superstition—of false worship; those who call attention to the insanitary state of our educational system are rarely treated seriously by the public at large; that we neglect just those means which probably will most conduce to the formation of character is almost unrecognised even by the great body of professed educationists. It is almost always by appeals to our pockets and not to our higher moral nature that attempts to improve our teaching are made successful.

In a word, science is not yet included within the purview of practical politics. No better evidence of this could be offered than the fact that the chief Liberal organ of our daily press, the other day, at the end of fifty years, in reviewing with just pride its history, although it told us much of wars, practically made no reference whatever to the victories of scientific workers—whose labours during the period have revolutionised the business of the world and brought greater happiness to untold millions. How is it possible, with such evidence before us, to boast of the present as an age of culture?

As it is well recognised that no movement can prosper in this country until it becomes popular, those who are informed on questions such as I have referred to are in duty bound to speak out. Let me beg any members of our School Board who are present here and such others as may happen to become aware of this appeal to take it most carefully into their consideration. The introduction of more rational methods

of teaching is, I believe, a matter of the utmost national importance. Recent events have brought home to us more clearly than has ever before happened, how absolutely our future depends on our preparedness to face the competition, the jealousy and even the ill-will of the world; nor must we forget how absolutely, also, apart from any question of competition, our home comfort, as I have said, depends on our ability to understand our surroundings and to act rationally.

The School Board is not itself aware, I believe, what has already been done under its auspices; it is not yet the habit of its members to interest themselves in educational method—no great blame to them, as teachers also have hitherto paid but a very insufficient share of attention to the subject. They probably do not know, therefore, that during the past five years or so a revolution has been silently effected in a district close at hand over the water, the Tower Hamlets and Hackney district—a revolution effected under their auspices but with little encouragement from them, perhaps, which some of us think will ultimately spread throughout the land, affecting schools of all grades; and, for the sake of our country, we trust this may very soon come about. The School Board may, at least, have the satisfaction of knowing that the Incorporated Association of Head Masters—who assembled in solemn conclave at the Mansion House a few days ago—agreed to recommend to the attention of educational authorities a scheme of elementary scientific exercises, which is, in principle, that long since adopted in certain of its schools. Many have held the opinion that the reform which our school system is so much in need of will come from below—that the higher grade schools must eventually be led to do their duty

by the example set by the elementary schools. I venture to claim this action of the head masters as proof positive that the truth of this proposition is at last established; also to claim it as evidence that the School Board for London has been engaged in a good work of which it has reason to be very proud.

In order to meet the argument—if argument it be—which some misguided, not to say selfish, people are sure to use, that the School Board has, in a measure, exceeded its functions, let me at once point out that it has but dealt with one necessary element in education—that in the future, just as all *must* be taught to read, so all *must* be taught the elements of scientific method. Moreover, although it is known how much we are striving to give *technical education*, it is, perhaps, not so generally known that those who are engaged in such work are agreed that it is all but impossible at the present time to give true technical education in this country owing to the extraordinarily defective condition of our preliminary school training: so that unless the children in elementary schools are taught to appreciate the main principles of scientific method—aye, not merely to appreciate them, but are so practised in their use that they become part of their nature—it will be impossible for them afterwards to avail themselves properly of the higher training which is offered to them and which alone can render them thoroughly competent as industrial and domestic workers. At the recent meeting of the Association of Directors and Organising Secretaries for Technical and Secondary Education, the chairman, Mr. Reynolds, of Manchester, a highly experienced worker in this field, remarked that whereas elementary schools should be training institutions, under our present system they

were merely places for imparting information, all aiming at earning money grants. The great difficulty the technical schools had to contend with, he said, was the unpreparedness of the country and the want of systematic organisation: they could not get pupils who had been properly prepared. It would seem, he added, that the real needs of the country as an industrial and manufacturing country were entirely ignored. They desired to press upon Parliament the necessity for a revision of the whole system of education. It was the duty of some one to put into their hands proper material on which they could work and until this was done their functions could not be satisfactorily carried on. At present they were called upon to undertake work which was not technical education at all but merely playing with it.

Complaints such as this are heard everywhere and it is not merely asserted that we neglect but that we hinder, which is far worse: for many think that the kind of teaching we give at the outset and, indeed, throughout the school course, acts protectively like vaccination, more or less closing the mind and rendering it, if not immune from attack, at least feebly susceptible of receiving higher training.[1]

It is, I trust, unnecessary for me to show that there is no desire to introduce a new subject into the already overcrowded school programme; it will be understood that the object has been to introduce improved and practical methods of teaching, to lighten, rather than to increase, the burden now put

[1] Mention was made here, at considerable length, of the work done by Messrs. Gordon and Heller in giving instruction in scientific method in the Board Schools; as this is referred to in Article XV (p. 244) the account is omitted.

upon both scholars and teachers. We complain that under the present system the work done in schools is mechanical; that it involves practically nothing but lesson learning, no proper attempt being made to educate or call forth the innate ability more or less latent in every child, nor to so discipline the minds of children that they are prepared to carry on their studies on leaving school. Our system claims to be a practical system, as the children are set to make measurements and to find out things themselves, thereby learning to do things—which is much better than being told about them—and to help themselves. It is a quantitative system, as the children are encouraged to weigh and measure whenever possible and we gradually lead them to be exact and thrifty. It is a logical system, encouraging thoughtfulness, as all the exercises are based on definite motives which must first be understood; and the information gained in the course of the experiments is made use of in drawing conclusions and in devising further test experiments. It is an anti-dogmatic system, as answers to questions are sought and obtained experimentally; each child, in fact, engages in research. It is a useful system, as most of the exercises have to do with the common objects or practices of daily life. It is an ennobling system, as it gives play to the imagination and tends to turn the imagination, not inwards, but outwards.

As I have said over and over again when speaking of the work, the great object in view is the formation of character—to turn out pupils who have learnt to be careful, exact, observant and thoughtful and who therefore can be trusted. For such work as I have described we claim the first position next to the three

R's; it is desirable to state this plainly, as this will be the main issue to which any committee of investigation must direct its attention.

I have already pointed out how in some ways the experience gained in the elementary schools is likely to influence those of higher grade; but there are other ways not yet mentioned to which I may briefly refer. First and before every other advantage which the new scheme presents comes the use of the balance—an instrument which, in the future, I believe, will be regarded in all schools as an extraordinarily potent means of effecting moral culture.

I hope some day to see teachers generally persuaded that the balance is the most valuable educational weapon at their disposal, not a mere instrument for proving principles. Then every child will be taught to weigh *when very young*, and will learn to treat the balance with utmost care and reverence and in every way to preserve it from harm; moreover, the discipline of weighing properly will be continued until it becomes a fixed habit. The point is one of extreme importance, on which I desire to lay all possible emphasis. Conversion to the true faith will, I feel sure, be gradually effected as experience is gained. It is not a matter on which a valid opinion can be pronounced without extended trial. Then I am often told by teachers in secondary schools that the whole class must be doing one and the same thing at a particular time and that work begun at one lesson must be completed within the time allotted to the lesson. The experience of the Board Schools shows, however, that considerable latitude is possible in these respects; in fact, it is usually necessary to allow different members of the class to occupy themselves somewhat differently in

order to eke out the modest supply of apparatus at disposal. But in this direction there is obviously much opportunity for careful experimenting. I believe that we shall ere long come to the conclusion that rigid time-tables in which every five minutes during the day has its allotted task must give way to a far more elastic plan; and I even look forward to the time when, instead of confining children at desks all day long, we shall allow them to move about in an orderly manner and do much of their work at benches such as we have in our science schools; and that we shall then encourage them to talk together about their work as young children will do when left to themselves: in fact, that our whole system will be one tending to develop and expand *childlike habits of mind*, which all capable observers agree are infinitely in advance of those of ordinary grown-up people.

All these are matters requiring most careful attention from the School Board and to study them it should organise an intelligence department, as experience shows that they cannot be left to the Education Department; indeed, if education is to be treated in the future as a science and it be recognised that progress in education can only be the outcome of experimental investigation, it will often be necessary for the School Board to take cognisance of the doings of the inspectors and to require that they maintain an open-minded attitude towards attempts to improve the teaching. The sure method would be to require that the inspectors should, occasionally, themselves go back into training—a still better plan would be to require of each one of them, at stated intervals, a piece of research work.

XIV

ON THE TEACHING OF NATURAL SCIENCE AS A PART OF THE ORDINARY SCHOOL COURSE AND ON THE METHOD OF TEACHING CHEMISTRY IN THE INTRODUCTORY COURSE IN SCIENCE CLASSES, SCHOOLS AND COLLEGES.

HOWEVER fully it may be admitted by the few that it is important, nay essential, that all members of the community, whatever their station or occupation, should receive some instruction in the elements of Natural Science during their school career, the general public have not as yet had brought home to them with sufficient clearness that just as a knowledge of foreign languages is essential to all who are brought into intercourse with foreigners, so in like manner is a correct knowledge of the elements of natural science of direct practical value to all in their daily intercourse with Nature, apart from the pleasure which such knowledge affords. In fact, judged from a purely utilitarian standpoint, the advantages to be derived from even the most elementary acquaintance with what may be termed the science of daily life are so manifold that if once understood by the public, the claims of science to a place in the ordinary school course

must meet with universal recognition. To quote Huxley: "Knowledge of Nature is the guide of practical conduct . . . any one who tries to live upon the face of this earth without attention to the laws of Nature will live there for but a very short time, most of which will be passed in exceeding discomfort: a peculiarity of natural laws, as distinguished from those of human enactment, being that they take effect without summons or prosecution. In fact, nobody could live for half a day unless he attended to some of the laws of nature; and thousands of us are dying daily, or living miserably, because men have not yet been sufficiently zealous to learn the code of Nature."

But it is also and mainly on other and far higher grounds that we should advocate universal practical teaching of the elements of natural and more particularly of so-called physical science: viz., that it tends to develop a side of the human intellect which, I believe, I am justified in saying is left uncultivated even after the most careful mathematical and literary training: the faculty of observing and of reasoning from observation and experiment. It is entirely from this latter point of view that I shall venture to propound a scheme for teaching the elements of that branch of physical science with which I am most intimately acquainted.

This Exhibition affords some few noteworthy illustrations of the way in which the importance of teaching the elements of natural science has received practical recognition in our schools. Thus we have indications of the work being done by the Birmingham School Board; the London School Board call attention to their system of training pupil-teachers in science; Mr. Robins shows plans of one of the best, if not the

best, equipped school chemical laboratory—that of the Manchester Grammar School. Also, it is well known that at many of the larger schools, such as Clifton College, Eton, Harrow, Rugby, St. Paul's, Giggleswick and the North London Collegiate School for Girls, ample provision is made for teaching one or more branches of natural science; and not a few other examples might be quoted. But in how large a proportion of the schools throughout the country is such training neglected? And there is much cause for complaint in the fact that in those schools in which science is taught, it is after all in most cases but a kind of "refuge for the destitute," only those who have failed on the classical side and those judged to be inferior in intellect being turned over to the so-called modern side. This is probably due to a variety of causes: to the ignorance already referred to of the public of the importance and value of such training—or it would be demanded of the schools; to the ignorance of even the barest elements of science of the majority of teachers in charge of schools; to the want of good science teachers and of suitable books; to the supposed expense of teaching science; and lastly—and I believe this to be the most important of all the causes which operate against the teaching of science—to the imperfection of our method of teaching: there can be little doubt, in fact, that the majority of teachers of the generally recognised subjects who have themselves no scientific knowledge see clearly enough that very little good comes of teaching science in the manner in which it is commonly taught in schools.

The great objection to the method at present in vogue appears to me to be that it is practically the same whether science is taught as a part of the general

school course or whether it is taught professionally: in other words, a lad studies chemistry, for example, at school in just the same way as at a science college, the only difference being that he does not carry his studies so far at school as at college. This, I believe, is the primary fault in our present system. In my opinion, no single branch of natural science should be selected to be taught as part of the ordinary school course but the instruction should comprise the elements of what I have already spoken of as the science of daily life and should include astronomy, botany, chemistry, geology, mechanics, physics, physiology and zoology—the olla podrida comprehended by Huxley under physiography but which is perhaps more happily expressed in the German word *Naturkunde*—in so far as is essential to the understanding of the ordinary operations and objects of Nature, the teaching from beginning to end being of as practical a character as possible and of such a kind as to cultivate the intelligence and develop the faculties of observing, comparing and reasoning from observation; and the more technical the course the better. The order in which these subjects should be introduced is matter for discussion; personally, I should prefer to begin with botany and to introduce as soon as possible the various branches of science in no particular order but that best suited to the understanding of the various objects or phenomena to which the teaching for the time being had reference. The extent to which instruction of this kind is given must entirely depend on the class of scholars.

There are few teachers capable of giving such instruction and fewer books of a character suited to ordinary requirements. The development of such a

system will, in fact, require the earnest co-operation of a number of specialists; but apart from the difficulty of securing efficient co-operation, there is no reason why some such scheme should not be elaborated at no distant date. If action is to be taken, however, there must be no delay or the opportunity will be lost. I trust that this meeting will be prepared to give much attention to this question and that it may be possible to continue the discussion on other platforms, as it is fundamentally important and deserving of the most serious consideration of educationalists. No doubt it will be said that the object of introducing the teaching of science into the school course is to afford mental training of a particular character, not the inculcation of useful knowledge; and that this end can be secured by teaching well some one branch of science. Admitting that this has been the case, however, there is no reason why it should be in the future: if while developing the intellect it be possible—and it certainly is—to impart much valuable information; and if—as it certainly is—the teaching be rendered easier and more attractive because it has direct reference to the familiar objects and operations of Nature. We cannot, indeed, any longer afford to grow up ignorant of all that is going on around us and without learning to use our eyes and our reasoning powers; we cannot afford to be unacquainted with the fundamental laws of health; but we must ever remember "that knowledge of Nature is the guide of practical conduct" and no effort must be spared to render our system of education an effectual preparation and truly adapted to the exigencies of practical life. The female educators appear already to have grasped the importance of such teaching and under the guise of domestic economy

much that I advocate is being taught in girls' schools; it is to be hoped that ere long something akin to the domestic economy course in girls' schools will find a place in boys' schools.

To pass now to the consideration of the mode of teaching my own special subject in science classes such as those held under the auspices of the Science and Art Department and in the introductory course for students in science schools and colleges generally. To deal first with the former. Inspection of the syllabus for the elementary stage, together with the study of the examination papers of the past few years, will show that the student is mainly required to have an elementary knowledge of the methods of preparing and also of the properties of the commoner *non-metallic* elements and their chief compounds. There is thus practically no distinction to be drawn between the knowledge required of students under the Science and Art Department and of those who are making the study of chemistry the business of their lives. But surely it is not the function of the Science and Art Department to train up chemists and I am satisfied that it is neither their desire nor their intention to do so; their object undoubtedly is to encourage the teaching of chemistry as a means of cultivating certain faculties and in order that the fundamental laws of chemistry may be understood and their commoner applications realised. It is not difficult to understand how the system has grown up and why it is maintained; I do not believe it is because the Department consider it a satisfactory one: it is because they know full well that a better system is not yet developed and that it would be unwise to legislate far in advance of the intelligence and powers

of the majority of the teachers. With all deference, however, I venture to add that the programme has been drawn up too much from the point of view of the specialist and that too little attention has been devoted to it from the point of view of the educationalist. The course I am inclined to advocate would be of a more directly useful character. There is no reason why in the beginning attention should be confined to the non-metals, especially when certain of the metals enter so largely into daily use; and provided that it involve no sacrifice of the opportunities of developing the faculties which it is our special object to cultivate by the study of chemistry, there is no reason against, but every reason for, selecting subjects of everyday importance rather than such as are altogether outside our ordinary experience, such, for example, as the oxides of nitrogen: even chlorine, except in relation to common salt, might be omitted from special study. The presumed distinction between so-called inorganic and organic chemistry should be altogether put aside and forgotten and the elements of the chemistry of the carbon compounds introduced at a very early stage in order that the phenomena of animal and plant life might come under consideration. To give the barest possible outline of a programme, I would include such subjects as the following in the syllabus :—

The chemistry of air, of water and of combustion. The distinction between elements and compounds. The fundamental laws which regulate the formation of compounds and the chemical action of bodies upon one another (*i.e.*, the nature of so-called chemical change). The chemical properties of the metals in ordinary use with special reference to their uses and

the action upon them of air, water, etc. The composition of natural waters. The distinction between fats, carbohydrates and albuminous substances in so far as is essential to the understanding of the relative values of different foods and respiration and growth in animals and plants (outlines of the chemistry of animal and plant life, in fact); the nature of the processes of fermentation, putrefaction and decay.

The instruction in these subjects should in all cases be imparted by means of object lessons and tutorial classes; lectures pure and simple should, as far as possible, be avoided. The students should by themselves go through a number of practical exercises on the various subjects. I would abolish the teaching of tables for the detection of simple salts, the teaching of analysis, as at present conducted, being, I believe, in most cases, of very little if any use except as enabling teachers to earn grants.

In schools and colleges in which chemistry is taught as a science, ostensibly with the object of training young people to be chemists, it is the almost invariable practice that the student first devotes more or less time to the preparation of the commoner gases and then proceeds to study qualitative analysis; quantitative determinations are made only during the later period of the course. I believe that the system has two great faults: it is too mechanical and it does not sufficiently develop the faculty of reasoning from observation; moreover actual practice in measurement is introduced far too late in the course. It is of great importance that the meaning of the terms equivalent, atomic weight, molecular weight, should be thoroughly grasped at an early stage: according to my experience this is very rarely the case; no difficulty is

met with, however, if the beginner is taught to make a few determinations himself of equivalents, etc., as he very well may be. It is not necessary here to enter into a more detailed criticism but I propose instead to give a brief description of a modification of the existing system which in my hands, in the course of about four years' experience, has furnished most encouraging results and which I venture to think is worthy of an extended trial.

Instead of merely preparing a variety of gases, the student is required to solve a number of problems experimentally: to determine, for example, the composition of air and of water; and the idea of measurement is introduced from the very beginning as the determination is made quantitatively as well as qualitatively. Each student receives a paper of instructions — two of which are printed as an appendix to this paper — which are advisedly made as bare as possible so as to lead him to find out for himself or inquire how to set to work; he is particularly directed that, having made an experiment, he is to enter in his notebook an account of what he has done and of the result; and he is then and there to ask himself what bearing the result has upon the particular problem under consideration: having done so, he is to write down his conclusion. He is thus at once led to consider what each experiment teaches: in other words, to reason from observation. Apart from the mental exercise which this system affords, if the writing out of the notes be properly supervised, the literary exercise which it also affords is of no mean value.

In illustration, I may here very briefly describe the manner of working out the second problem in

the course. The problem being: To determine the composition of water, the student receives the instruction: 1. Pass steam over red-hot iron brads, collect the escaping gas and apply a light to it. (N.B. The gas thus produced is called hydrogen.) He is provided with a very simple apparatus, consisting of a small glass flask containing water, joined by a narrow bent glass-tube to an iron tube (about 9 inches long and $\frac{1}{2}$ to $\frac{3}{4}$ inch wide) in which the brads are placed, a long glass tube suitably bent for the delivery of the gas being attached to the other end of the iron tube. Plaster of Paris is used instead of corks to make the connections with the iron tube. The iron tube is supported over a burner and heated to redness; the water in the flask is then heated to boiling and the steam thus generated is passed over the brads; the escaping gas is collected over water in the usual manner. Having made this experiment and observed that on passing steam over red-hot iron the gas hydrogen is produced, the student proceeds to consider the bearing of this observation. The hydrogen must obviously be derived either from the water or from the iron, if not from both. Those who already know that iron is iron, so to speak, at once infer that the hydrogen is derived from the water: it is, however, pointed out that even if it be known that iron is a simple substance, this observation taken alone does not prove that hydrogen is contained in water.

2. The student next learns to prepare hydrogen by the ordinary method of dissolving zinc in diluted sulphuric acid and makes a few simple experiments whereby he becomes acquainted with the chief properties of the gas.

3. Having done this, he is instructed "to burn

dry hydrogen at a glass jet underneath a cold surface and to collect and examine the product." The product is easily recognised as water. The immediate answer to the question "What does this observation teach?" is, that since iron is absent, taken in conjunction with experiment 1, the production of water on burning hydrogen in air, the composition of which has already been determined, is an absolute demonstration that hydrogen is contained in water.

4. Having previously studied the combustion of copper, iron and phosphorus in air and having learnt that when these substances burn they enter into combination with the oxygen in air, the student is also led to infer from the observation that hydrogen burns in air, producing water, that most probably it combines with the oxygen and that water contains oxygen besides hydrogen. It may be, however, it is then pointed out, that the hydrogen, unlike the phosphorus, etc., combines with the nitrogen instead of with the oxygen or perhaps with both. He is, therefore, instructed to pass oxygen over heated copper, weighing the tube before and after the operation; and to heat the "oxide of copper" subsequently in a current of hydrogen. He then observes that water is formed, the oxygen being removed from the copper: and since nitrogen is absent, it follows that water consists of hydrogen and oxygen and of these alone.

5. By repeating this last experiment so as to ascertain the loss in weight of the copper oxide tube and the weight of water produced, the data are obtained for calculating the proportions in which hydrogen and oxygen are associated in water.

In practice, the only serious difficulty met with has been to induce students to give themselves the trouble

to consider what information is gained from a particular observation; to be properly inquisitive, in fact. I cannot think that this arises, as a rule, from mental incapacity. When we consider how the child is always putting questions and that nothing is more beautifully characteristic of young children than the desire to know the why and wherefore of everything they see, I fear there can be little doubt that it is one of the main results—and it is indeed a lamentable result—of our present school system that the natural spirit of inquiry, inherent to a greater or less extent in every member of the community, should be thus stunted in its growth instead of being carefully developed and properly directed.

Having studied, in the manner which I have described, air, water, the gas given off on heating common salt with sulphuric acid and the ordinary phenomena of combustion, the student next receives a paper with directions for the comparative study of lead and silver (see Appendix). The experiments are chosen so as to afford an insight into the principles of the methods ordinarily employed in qualitative and quantitative analyses. The student who has conscientiously performed all the exercises is in a position to specialise his studies in whatever direction may be desirable.

The system I have thus advocated undoubtedly involves far more trouble to the teacher than that ordinarily followed; but the student learns far more under it and I assert with confidence that the training is of a far higher order and also of a more directly useful character. I believe it to be generally applicable and that it would be of special advantage in those cases in which only a short time can be devoted to the study of chemistry—as in evening classes and

medical schools. At present the only practical teaching vouchsafed to the majority of students in our large medical schools is a short summer course during which they are taught the use of certain analytical tables: as a mental exercise, the training they receive is of doubtful value; the knowledge gained is of little use in after life; and the course certainly ought not to be dignified by being spoken of as a course of Practical Chemistry: *test-tubing* is the proper appellation. It is not a little remarkable also that even the London University Syllabus nowhere specifies that a knowledge even of the elements of quantitative analysis will be required of candidates either at the Preliminary Scientific or First M.B. Examination and this too when, as is well known, an analysis to be of any practical value must almost invariably be quantitative. It is little less than a disgrace to the medical profession that a subject of such vital importance as chemistry should be so neglected.

If, however, we are to make any change in our method of teaching science, if we are to teach science usefully throughout the country, two things are necessary: teachers of science must take counsel together and the examining boards must seriously consider their position. There can be little doubt that in too many cases the examinations are suited to professional instead of to educational requirements; and that the professional examinations are often of too general a character and do not sufficiently take into account special requirements.

APPENDIX

Problem: to Determine the Composition of Air

N.B.—Immediately after performing each experiment indicated in this and subsequent papers, write down a careful description of the manner in which the experiment has been done, of your observations and the result or results obtained and of the bearing of your observations and the result or results obtained on the problem which you are engaged in solving. Be especially on your guard against drawing conclusions which are not justified by the result of the experiment; but, on the other hand, endeavour to extract as much information as possible from the experiment.

1. Burn a piece of *dry* phosphorus in a confined volume of air, *i.e.* in a stout Florence flask closed by a caoutchouc stopper. Afterwards withdraw the stopper under water, again insert it when water ceases to enter and measure the amount of water sucked in. Afterwards determine the capacity of the flask by filling it with water and measuring this water.

N.B.—The first part of the experiment requires care and must be done under direction.

2. Allow a stick of phosphorus lashed to a piece of stout wire to remain for some hours in contact with a known volume of air confined over water in a graduated cylinder. After noting the volume of the residual gas, introduce a burning taper or wooden splinter into it.

N.B.—The residual gas is called *nitrogen*.

3. Burn a piece of dry phosphorus in a current of air in a tube loosely packed with asbestos. Weigh the tube, etc., before and after the experiment.

4. Repeat Experiment 2 with iron-borings moistened with ammonium chloride solution. Preserve the residual gas.

5. Suspend a magnet from one arm of a balance; having dipped it into finely divided iron, place weights in the opposite pan; when the balance is in equilibrium, set fire to the iron.

6. Pass a current of dry air through a moderately heated tube containing copper. Weigh the tube before and after the experiment; also note the alteration in the appearance of the copper.

7. Strongly heat in a *dry* test-tube the red substance obtained by heating mercury in contact with air. At intervals plunge a glowing splinter of wood into the tube. Afterwards note the appearance of the sides of the tube. (Before performing this experiment ask for directions.)

N.B.—The gas obtained in this experiment is named *oxygen.*

8. Heat a mixture of manganese dioxide and potassium chlorate in a dry test-tube; at intervals plunge a glowing splinter into the tube. This experiment is to acquaint you with an easy method of preparing oxygen in quantity.

9. Prepare oxygen as in Experiment 8 and add it to the nitrogen from Experiment 4 in sufficient quantity to make up the bulk to that of the air taken for the latter experiment. Test the mixture with a burning taper or splinter.

10. Dissolve copper in nitric acid and collect the escaping gas (nitric oxide); add some of it to oxygen and some of it to air.

11. Fill a large flask provided with a well-fitting caoutchouc stopper and delivery tube with ordinary tap water and gradually heat the water to the boiling point; collect the gas which is given off in a small cylinder and add nitric oxide to it. Also collect a sufficient quantity in a narrow graduated cylinder and treat it as in Experiment 2.

Comparative Study of Silver and Lead

Silver.—*Symbol*, Ag. (*Argentum.*) *Atomic weight*, 107·67. *Specific heat*, ·05701.

Lead.—*Symbol*, Pb. (*Plumbum*). *Atomic weight*, 206·47. *Specific heat*, ·03140.

1. Determine the relative density of lead and silver at a known temperature by weighing in air and in water.

2. Separately heat known weights of lead and silver for some time in the air, allow to cool, then weigh.

3. Separately convert known weights of lead and silver into nitrates; weigh the latter. From the data thus obtained calculate the *equivalents* of lead and silver.

4. Convert the known weights of nitrates thus obtained into chlorides; weigh the latter.

5. Compare the action on lead and silver of chlorhydric acid; of dilute and concentrated sulphuric acid, using the acid both cold and hot; and of cold and hot nitric acid.

6. Using solutions of the nitrates, compare their behaviour with chlorhydric and sulphuric acids, hydrogen sulphide, potassium iodide and potassium chromate. Ascertain the behaviour of the precipitate formed by chlorhydric acid when boiled with water and when treated with ammonia solution.

7. Compare the behaviour of lead and silver compounds on charcoal before the blow-pipe.

8. Tabulate the results of your experiments with lead and silver in parallel columns.

9. Ascertain whether the substances given you contain lead or silver.

10. Determine silver in an alloy of lead and silver by cupellation.

11. Study the method of determining silver volumetrically by means of a *standard solution* of ammonium thiocyanate. Determine the percentage of silver in English silver coinage.

12. Determine silver as chloride by precipitation.

13. Dissolve a known weight of lead in nitric acid, precipitate it as sulphate, collect and weigh the latter.

14. What are the chief ores of lead and silver? How are lead and silver extracted from their ores? How is silver separated from lead? How is it separated from burnt Spanish pyrites? What are the chief properties and uses of lead and of silver? State the composition of the chief alloys of lead and silver.

XV

THE HEURISTIC METHOD OF TEACHING OR THE ART OF MAKING CHILDREN DISCOVER THINGS FOR THEMSELVES

A CHAPTER IN THE HISTORY OF ENGLISH SCHOOLS

New times demand new measures and new men;
The world advances, and in time outgrows
The laws that in our fathers' days were best;
And, doubtless, after us some purer scheme
Will be shaped out by wiser men than we,
Made wiser by the steady growth of truth.

. . . . .

Our time is one that calls for earnest deeds.

LOWELL.

ALL who seriously study the history of education in our times must agree that, although it may be long ere we can cry *Eureka! Eureka!* of an ideally perfect system, recent experience justifies the assertion that we shall hasten the advent of that desirable time if we seek to minimise the didactic and encourage heuristic teaching; for the progress made of late, which is very considerable, is unquestionably due to the introduction of heuristic methods and exercises.

But many will ask—"What are heuristic methods? Even the word is strange to us!" they will add.

True, it is not yet in the dictionary; but it is scarcely possible to doubt that it is come to stay and will—nay, must—soon be there; indeed, its introduction as the watchword of a party seems really to meet a want, judging from communications I have received with reference to my paper on *Heuristic Teaching in Physical Science*, read at the International Conference on Technical Education, at the Society of Arts, in June 1897.

I first came across it in an eminently suggestive paper by Professor Meiklejohn, one of the most valuable by far of those read at the International Conference on Education held in connection with the Health Exhibition at South Kensington in 1884.

Heuristic methods of teaching are methods which involve our placing students as far as possible in the attitude of the discoverer—methods which involve their *finding out* instead of being merely told about things. It should not be necessary to justify such a policy in education. Unfortunately, however, our conceptions are blunted by early training or rather by want of training. Few realise that neither is discovery limited to those who explore Dark Continents or Polar Regions nor to those who seek to unravel the wonders of Nature; that invention is not confined to those who take out patents for new devices; but that, on the contrary, discovery and invention are divine prerogatives, in some degree granted to all, meet for daily usage and that it is consequently of importance that we be taught the rules of the game of discovery and learn to play it skilfully. The value of mere knowledge is immensely over-rated and its possession over-praised and over-rewarded; action, although appreciated when its effects are noted, is treated as the outcome of innate

faculties and the extent to which it can be developed by teaching scarcely considered.

Professor Meiklejohn, in the paper referred to, contends that the permanent and universal condition of all *method* in education is that it be heuristic; and goes on to say:—

> This view has its historic side; and it will be found that the best way, the truest method, that the individual can follow is the path of research that has been taken and followed by whole races in past times. This has, perhaps, been best put by Edmund Burke, probably the greatest constructive thinker that ever lived in this country. He says: "I am convinced that the method of teaching which approaches most nearly to the methods of investigation is incomparably the best; since not content with serving up a few barren and lifeless truths, it leads to the stock on which they grew: it tends to set the learner himself on the track of invention, and to direct him into those paths in which the author has made his own discoveries." It may be said, Professor Meiklejohn continues, that this statement is applicable to science and to science only. But I am prepared to show at the right time, that it is applicable to literature also, though not in the fullest extent and application of the method. The heuristic method is the *only* method to be applied in the pure sciences; it is the best method in the teaching of the applied sciences; and it is *a* method in the study of those great works of art in language by the greatest minds which go by the general name of literature.

It would be easy to support this contention by numerous other quotations: one will suffice—than which, however, none could be more impressive or striking. I refer to the words used by Lessing: "If the Almighty were in the one hand to offer me Truth and in the other the Search after Truth, I would humbly but firmly choose the Search after Truth"—words already cited by the Headmaster of University College, Mr. Eve, in advocating scholarly teaching of modern languages.

My own career has led me along lines entirely in harmony with the views expressed by Professor Meiklejohn—hence it is, perhaps, that I am become so strenuous an advocate of the doctrine he supports.

I can clearly trace the development of my [1] heuristic tendencies—which are certainly in a large measure innate, for my father was critical and inquiring—to one of my school-books—absolutely the only interesting one that came into my hands—to a literary work, *Trench's Study of Words;* and can well recollect how this book at once fascinated me—and not me alone but my father also, a commercial man, whose early training and career had been such as to leave him entirely unacquainted with subjects of the kind. I still vividly recall to mind how from this book, as a mere lad, I for the first time gained ideas as to the value of method—of what I should now call *scientific method.* It even taught me to appreciate Euclid, the deadly dulness of which subject long oppressed me as it does probably almost every boy or girl at school, for there was no meaning apparent in it as it was presented: it seemed in no way to connect itself up with any experience I had gained; but somehow, after reading Trench, the scales suddenly fell from my eyes, its logical character at least became evident and it was no longer so difficult to understand or to master—but I cannot say that it ever became interesting or its use obvious. This experience has haunted me

[1] Unfortunately, as I am sketching the history of a movement in which I have perforce taken a leading part, it will be difficult to avoid an egotistical form of statement—would that it were otherwise, for had more of those whose duty it is to work in such a field taken their fair share of the labour, there would not only have been no excuse for me to obtrude myself but the many necessary reforms would long ere this have been introduced into our system of teaching.

through life and has often led me to think how much I might have learned at school had I been properly taught or even provided with a few books giving insight into method, like Trench's; I owe to it more than to anything else the growth of a desire to promote the teaching of method.

As a student of science I was equally perverse. I had every desire to learn but didactic teaching seemed always to produce a sense of irritation. Practical work was intensely interesting, although it was only too often done in obedience to orders without the underlying philosophical motive being clear. The facts recited in the lecture-room, especially when accompanied by experimental illustrations, frequently came as revelations: but, on the whole, listening to lectures produced little abiding effect, one image following the other too quickly. Text-books I always found unattractive and unsatisfying—often nauseating, for I felt that I wanted to become a chemical cook myself, not merely to know what the dishes were made of and what they looked like on the table; however, I got through them and the measles lightly, without any serious disturbance of mental balance such as a hard fate and unreflecting educators impose on most students who are forced, by the pressure of examinations, to indulge unduly in food so indigestible and unpalatable. Happily the proper corrective was soon discovered: for being an omnivorous reader, it was my good fortune, at an early stage, to have my attention called to original literature. Needless to say, this proved to be intensely interesting, as glimpses of method were soon gained from it. Full emancipation came later—the haven being reached when I passed from the mainly didactic surroundings of an

English laboratory into the heuristic atmosphere of a German university. I seemed to escape into an Elysium.

Nevertheless, in the course of years, I had been insensibly compelled to swallow much poison and this had its inevitable effect. Impressed habits and convictions were not easily cast aside: so that when I started my career as a teacher, although I saw much reason to be dissatisfied with existing practices, it was only very gradually that I could divest myself of conventional articles of belief or make up my mind what changes were necessary and feasible. Therefore I can always fully sympathise with teachers whose convictions have been forced upon them—whose peace of mind was until recently undisturbed. It is easy to understand that it will be very difficult for them to enter fully into the spirit of the heuristic doctrines that are now being widely preached and still more so for them to apply methods which they have never previously been trained to understand.

My opportunity first came when I was appointed to take charge of the chemical classes established at Finsbury by the City and Guilds of London Institute for the Advancement of Technical Education.

It was clear from the outset that technical education was a superstructure that could only be safely erected on a solid foundation and it was equally manifest that such a foundation was nowhere sufficiently laid. I early came to the conclusion which, I believe, is now common to all who are competent to speak on such a matter: that until our school system had been entirely reorganised, the forces of higher education could not be brought properly into action; and consequently felt it to be my duty to labour at the groundwork.

The experience gained in the course of four years in conducting classes at Finsbury led me in 1884 to state my views publicly in a paper on the teaching of natural science as a part of the ordinary school course and on the method of teaching science in the introductory course in science classes, schools and colleges —a paper which was read at the Health Exhibition Conference already referred to.

Universal practical teaching of the *elements* of natural science, not merely of some one branch, was advocated on the ground that it tends to develop a side of the human intellect which is left uncultivated by the most careful literary and mathematical training —the faculty of observing and of reasoning from observation and experiments. The instruction was to comprise the elements of the science of daily life in so far as is essential to the understanding of the ordinary operations and objects of Nature and was to be from beginning to end of as practical a character as possible, such as would develop the faculties of observing, comparing and reasoning from observation.

The essential feature in the chemistry scheme was that students were to be set to work *to solve problems* experimentally. They were not merely to be told: "This is the case—satisfy yourself that it is by repeating the following experiment." Moreover, quantitative exercises were introduced at the outset and were insisted on as all-important. Lastly, the instruction was not confined to non-metallic elements but metals in common use and organic substances consumed as foods were also to be studied; oxides of nitrogen and other *objets de luxe*, which in no way concern our daily life, being relegated to the repertory of the professional chemist.

Meanwhile, many others were also fully aware of the unsatisfactory character of the system of teaching science in vogue and were seeking to improve the methods. One result of this activity was that in 1887 a committee was appointed by the British Association for the purpose of inquiring into and reporting on the methods of teaching chemistry in schools.

In 1888, at the Bath meeting, this Committee presented a report in which an account was given of replies received to a letter addressed to the headmasters of schools in which chemistry was taught. This report is full of instructive reading. In referring to the replies received to the question—*Which methods, in your opinion, are most likely to render the teaching effective as a mental discipline and as a preparation for subsequent instruction in the higher branches of the science or in applied chemistry?* the Committee remark:—

It is clear that the older plans of teaching, which are still largely used, are felt to be partly unsatisfactory and that by modifying them chemistry might be made much more valuable as a mental discipline for boys. In particular, protest is made against the undue proportion of time which is frequently assigned to qualitative analysis; indeed, the majority of teachers do not consider this to be the most valuable part of the subject. Others hold that it presents many advantages and is, on the whole, the best adapted to school work, especially when instruction has to be given to large classes of boys. But while most teachers strongly deprecate a rigid adherence to the present system and a few are able to point out the general lines on which the teaching might be more usefully conducted, it is evident that very few, if any, have yet put into operation a remodelled system of instruction. In fact, it appears that teachers stand very much in need of advice and assistance in preparing a modified scheme of teaching suitable for general adoption in schools. It has several times been suggested that

this Committee might be able to render important help in this direction.

The final paragraph also of the report is now historically interesting:—

> The Committee feel that these reports have put them in possession of the actual facts connected with the teaching of chemistry in schools and have made it clear that something should be done in the direction of promoting a more uniform and satisfactory treatment of the subject. The Committee think that some suggestions might now be made as to the method of teaching chemistry which should be followed in schools. If this can be done, it will certainly confer a great benefit on both teachers and examiners and will be likely to lead to a more emphatic recognition of the merits of the science as an instrument of elementary education.

Further reports were presented in the two following years, 1889 and 1890. The Committee did me the honour to include in these two series of *Suggestions for a Course of Elementary Instruction in Physical Science.* In principle, these suggestions were the same as those put forward in the paper read in 1884; but they mark a great development of the scheme, which had meanwhile assumed a more consistently logical form.

If any proof were needed that criticism to be effective must be constructive, the success achieved through the British Association Reports would afford all that was wanted. There is no doubt that the recommendations of the Committee have been of the greatest service in promoting the introduction of heuristic methods of teaching experimental science into schools.

It is easy to preach or profess apparently sound doctrine in vague and flowing periods; to be fully seized with what Professor Meiklejohn humorously

terms the afflatus of a crotchet; but when practice takes the place of profession it often turns out that the understanding arrived at was very imperfect. The issue of full details of a scheme was therefore a step of great importance. Moreover, whilst the reports have served to guide teachers and have practically been their text-books, their pupils have enjoyed the inestimable advantage of working without a manual before their eyes to deaden their powers of perception and initiative. The reports, in fact, foreshadow the ideal elementary text-book of the future—one that will be consulted by students only after the knowledge is gained by actual observation.

Although the course indicated in the British Association scheme was one that had been found to work well in practice, I had not had sufficient opportunity of using it with young children, my experience having been chiefly gained from observing its effect on less plastic material—mostly lads who had left school without receiving any scientific instruction. But being a profound believer in the superior intelligence of young children, holding also the pessimistic view that school training as often mars as it makes the career of a child, I was from the outset persuaded that the system would prove most useful in schools and be most applicable to them.

We are entitled already to claim, I believe, that this is now placed beyond question. On the appointment of Mr. Hugh Gordon, M.A., in January 1891, by the School Board for London, as their Science Demonstrator in the East London and Tower Hamlets Division—one of the four districts into which London is divided—work was commenced in a number of the schools under his charge and was gradually extended by

him and subsequently by Mr. Mayhowe Heller, B.Sc., until in June 1897 the British Association scheme was in operation in no fewer than 40 of the London Board Schools. The attack thus made on the outworks of our English educational system was extraordinarily successful from the first, owing to the fortunate accident which led to the selection of capable commanding officers; and it is difficult to exaggerate the value of the service rendered by the two gentlemen named. Mr. Gordon, by his determination and energy, took the fortress by storm, cutting asunder the big, tangled ball of official red tape in dauntless fashion and so captivating both the teachers and inspectors by his enthusiasm for the work as soon to make willing helpers of nearly all of them. A little shilling manual — *Elementary Course of Practical Science* (Macmillan and Co., 1893)—which he prepared for the guidance of teachers and others was also of signal service. His successor, Mr. Heller, showed equal devotion to the work and not only carried it on in the boys' schools but succeeded in introducing it into several girls' schools; he paid special attention also to the scientific side of domestic economy and may be said, indeed, to have given the first impetus to rational teaching of this all-important subject.

Miss Grace Heath—a teacher of the very greatest promise, whose premature death is deeply to be deplored—early obtained most promising results at the North London Collegiate School for Girls, where, in consequence, such work is gradually becoming regarded as of importance. But the most systematic trial given to the method in a girls' school has been that carried out at the Central Foundation School in Bishopsgate, London, by Miss Edna Walter, B.Sc. This lady has

embodied her experiences in an interesting paper read at the Liverpool meeting of the British Association in 1896, which was afterwards printed in *Education*.

The co-operation of examining bodies—which the British Association Committee pointed out was so much needed—is also gradually being secured. The Association of Headmasters in 1894 appointed a Major Scholarships Committee

> To call together representatives of bodies interested in the award of Scholarships and Exhibitions offered by County Councils and similar bodies, which take the holders from Secondary Schools to places of higher education; and, if possible, to formulate a scheme of examination that may be acceptable both to schools and higher institutions.

The syllabus framed by this Committee, based on the British Association scheme, was taken into consideration and further elaborated—especially the preliminary part dealing with simple physical measurements—by a Special Committee appointed in 1895 by the Headmasters' Association, which meanwhile had acquired the dignity of an incorporated body. The amended syllabus prepared by this Committee was received and adopted by the headmasters at their general meeting in January 1896. It will be quoted in full later on. Following the plan adopted by the British Association Committee in publishing a detailed scheme of work, the Headmasters' Committee happily took steps to make the syllabus they issued useful to teachers by giving ample indication of the kind of work students should do in the form of suggestions of suitable experiments—thus setting examining bodies generally an example which was much needed. At the same time, they made their position clear by pointing out that it was not intended that the teaching should be limited to the

experiments described and that it was hoped that the suggestions would be sufficient to indicate the lines on which the teaching should proceed and to assist teachers in inventing other experiments. A syllabus full of detail is naturally open to the theoretical objection that it may confine and stereotype teaching; but on the other hand so long as teachers need guidance—as the majority of those in schools do at present—it is of inestimable value in promoting sound teaching; for however slavishly a syllabus be followed, if it be a sound one good results will be obtained by its use. As the schemes in use are excessively unsatisfactory in most cases, we may probably congratulate ourselves, however, that the conventional syllabus is, as a rule, brief and vague and therefore does not greatly mislead if it render no assistance.

In 1895 steps were taken to invite a conference between the Local Examination Authorities at Oxford and Cambridge and the Headmasters' Committee for the improvement of the methods of Science Teaching in Secondary Schools. Eventually the Oxford and Cambridge authorities agreed to introduce into their examination scheme a syllabus in accordance with that adopted by the Incorporated Association of Headmasters, which should, for the present, be alternative with that previously used. It is evident, when the schedules they have issued are considered, that they have done their best to comply with the understanding arrived at; unfortunately, however, their instructions in no way whatsoever imply or involve heuristic teaching: it is only too clear that that which is fundamental in the recommendations of the British Association scheme has not been understood.

As early as 1893, the Education Department had

introduced into the Evening Schools Continuation Code a syllabus prepared by Mr. Gordon, based on his experience in carrying out the British Association scheme both in London schools and in evening classes which he held for the Surrey County Council. The syllabus was subsequently introduced into the Day Code as Course H of the Alternative Courses and also in a modified form, under the title Domestic Science, into Schedule IV of the Day School for Girls. It now ranks as a specific subject for boys.

The Joint Scholarships Board—the outcome of the Major and Minor Scholarships Committees, appointed originally by the Incorporated Association of Headmasters but now an independent and widely representative educational authority — in their various examinations make use of schemes which all involve the decision that elementary physical science shall be taught on the lines prescribed by the British Association Committee.

The subject of chemistry teaching in schools was taken into consideration in 1896 by a highly representative hybrid committee appointed by the Technical Education Board of the London County Council. The recommendations of this committee, embodied in their report presented to the Technical Education Board in January 1897, also in all respects endorsed the opinions of the British Association Committee. Great impetus has been given to the rational teaching of elementary science in the London district by the enlightened action taken by Dr. Garnett and Dr. Kimmins, on behalf of the Technical Education Board, in advocating practical work. In a recent course of lectures to teachers, at the winter meeting in London organised by the College of Preceptors, Dr. Kimmins

gave most important testimony to the success achieved in schools using the headmasters' syllabus and also earned the gratitude of teachers by the hints he gave on methods of carrying on the work.

Lastly, it may be mentioned that the authorities of the University of London have recently taken the all-important step of prescribing *General Elementary Science*—which includes the elements of chemistry, mechanics and physics—as an obligatory subject at the Matriculation examination. But unfortunately the syllabus provided is a very unsatisfactory and old-fashioned one and is scarcely calculated in any way to influence favourably the *methods* of teaching science in schools. It could not well be otherwise, however, as no one fully aware of the progress that has been made in schools of late years, with knowledge of the details of such work, appears to have been placed on the Committees concerned in drafting the syllabus; and almost any rational scheme is bound to be wrecked by a plethora of invertebrate opinion. This is the more to be regretted as there is little doubt that whereas formerly teachers in schools were much behind the times they are now considerably in advance of their professional brethren and should have been taken into their councils. Indeed, as a class, professional teachers of physical science are proving strangely conservative and apathetic students of method—at a time, too, when there is paramount need for activity and infinite opportunity for its exercise. It is, perhaps, permissible to regard the fact that such is the case as conclusive evidence of the want of proper and especially of wide heuristic training, for it is evidently quite a mistake to assume that the profession of science nowadays makes men truly and broadly scientific, however

scientifically they may be able to carry on work in some narrow and highly specialised field of investigation.

For the benefit of literary friends who may here adventure the remark, "This is because you have had no proper literary training," let me say at once: It is nothing of the kind; it is simply because "science" is taught unscientifically—by literary methods, in fact, without sufficient regard to its essentially heuristic character. Had the literary party had command of the methods we are seeking to introduce, they would long ere this have effected the reforms we desire to bring about, the field having been in their possession for generations. Either this is true or they are incompetent to understand and use the weapons at their disposal.

But there is no need for us to bicker about small matters and there is no inherent antagonism between the views of our two schools when these are properly stated; the difficulties arising in practice are due to want of understanding and prejudice—I am bound to say, almost entirely on the literary side—when not to wanton disregard or blind ignorance. What is required now is that both parties should recognise that they have the same purpose in view and that there must be a judicious fusion of interests.

Before discussing various points of detail, it will be well to call attention to the syllabus of the course of instruction in elementary science, based on the British Association scheme, which has been adopted by the Incorporated Association of Headmasters (Appendix A). The syllabus is prefaced, it will be noticed, with a number of explanatory remarks which are of considerable importance and interest as showing the

point of view from which the instruction should be given.

There are many points in connection with the scheme of work embodied in this syllabus which may be dwelt on with advantage, especially on behalf of those unacquainted with such work and who desire to introduce the subject.

The question of attitude comes first. It is true the teaching of all subjects is now made infinitely more interesting than was formerly the case even in my school days, owing to great improvements in the books used and also owing to the introduction of illustrations and demonstrations such as were formerly undreamt of; and at the same time teachers have been growing more and more consistently liberal in their views. Yet, with rare exceptions, the attitude of teacher to pupil remains the same—it is essentially didactic; the aphorism, "Knowledge is power," narrowly interpreted, is still the guiding principle. But this cannot any longer be permitted.

A great object lesson in the value of scientific forethought has recently been given to the world by Nansen. Earlier Arctic expeditions had been conducted by men equally brave—but none had previously sought, as he did, to prepare themselves for every contingency by early training and by thinking out in advance all the conditions of the problem. Our educators are mostly in the condition of the old Arctic explorers: often brave, intelligent and self-sacrificing as they were; keen to render service and to achieve distinction for their country; yet in a sense very old-fashioned as well as untrained. The time is now come when we can only work on Nansen lines: teachers must display wider knowledge, wider grasp of their subject, more

forethought, more power of appreciating the conditions of the problem they are called on to solve, more willingness to advance, greater bravery in facing change—whatever trouble it may involve, higher conceptions of the moral duties of their calling,

It must from the outset and ever be remembered that the great object in view in education is to develop the power of initiative and in all respects to form the character of the pupil. The appreciation of this contention is crucial. "The pious Pestalozzi is filled with measureless remorse when he finds that he has *given* a little boy a conception instead of inducing him to find it himself," remarks Professor Meiklejohn. So should every teacher be; and if the feeling expressed in this sentence can but be made to rankle in the mind of every teacher the end is achieved. Schools will then become educating institutions; the didactic instruction which poisons our existence at the present day will be properly recognised as a fell disease.

It is necessary to insist on this over and over again, as even among those who are become advocates of heuristic training there is often incomplete recognition of the fundamental importance of observing such an attitude toward learners. The following passage, for example, occurs in the chapter headed "Physical Science" in Spencer's *Aims and Practice of Teaching Physical Science* (London, 1897, C. J. Clay and Sons), to which I have contributed the chapter on Chemistry.

> A great deal has been written in favour of the Research attitude on the part of the learner. But despite the force of some of the arguments adduced, it may be doubted whether this attitude is the proper one for a beginner. At the commencement of a science course the teaching cannot be too simple and it must be very clear and definite. Each step taken should logically follow from the work already done, and every experi-

ment should be undertaken with a definite object which should be fully understood and appreciated by the class. In working out a course of this kind, the *teacher* might, with advantage, follow an imaginary research path into the subject but the scholars may not become conscious of this and it is quite unnecessary that they should. If scholars are taught to observe the progress of an experiment in a vague sort of way and asked to deduce results from their observations, without being told definitely what to look for and how to look for it, the only result of the work is waste of time. In fact, until the scholars have acquired a little knowledge of the subject, it is useless to expect them to reason for themselves in the way necessary to follow out even the simplest research. Reasoning of this kind involves a knowledge of the facts and principles of the subjects and a beginner's time is best employed in acquiring this knowledge under the guidance of a competent teacher!

This presentment of the question may appeal to some who are not versed in the work. It is no question, however, of force of arguments adduced but one of facts established and of experience gained in practice among scholars of every type. It is in no sense mere opinion on my part but a conviction gradually forced upon me and established beyond all doubt by actual trial and observation during many years past, that the beginner not only may but must be put absolutely in the position of an original discoverer; and all who properly study the question practically are coming to the same opinion, I find. Young children are delighted to be so regarded, to be told that they are to act as a band of young detectives. For example, in studying the rusting of iron, they at once fall in with the idea that a crime, as it were, is committed when the valuable, strong iron is changed into useless, brittle rust; with the greatest interest they set about finding out whether it is a case of murder or of suicide, as it were—whether something

outside the iron is concerned in the change or whether it changes of its own accord.

A lady teacher who had thus presented the case to a class of young girls told me recently that she had been greatly amused and pleased to hear one of the girls, who was sitting at the balance, weighing some iron that had been allowed to rust, suddenly and excitedly cry out, "*Murder!*" This is the very attitude we desire to engender; we wish to create lively interest in the work and to encourage it to come to expression as often, as emphatically, as freely as possible.

It is of no use for the teacher merely to follow an imaginary research path: the object must ever be to train children to work out problems themselves and to acquire the utmost facility in doing so. Of course, the problems must be carefully graduated to the powers of the scholars and they must be insensibly led; but do not let us spoil them by telling them definitely in advance what to look for and how to look for it: such action is simply criminal.

My experience teaches me also that it is the grossest libel on young scholars to say that it is useless to expect them to reason for themselves in the way necessary to follow out the simplest research; but, unfortunately, if you substitute teachers for scholars this is too often a true statement and here the supreme difficulty of properly carrying out heuristic teaching comes in. It is the teachers who are preventing advance. Let us teachers recognise this; but do not let us overlook and misrate the powers of young children. Let us try what we can do and if we do not at first succeed let us try and try again; we shall surely succeed if we can only adopt this attitude.

But if we fail let us give up the work as soon as possible and leave it to others to succeed where we have failed. No other policy is an honest one—for the teaching of young children should never be regarded as a perfunctory task but as a sacred office. The whole policy of the teacher's duty is summed up in one little word, yet the most expressive in the English language: it is to train pupils to *do*. On this it is easy to base a simple test of competency.

It is needless to say, young scholars cannot be expected to find out everything themselves; but the facts must always be so presented to them that the process by which results are obtained is made sufficiently clear as well as the methods by which any conclusions based on the facts are deduced. And before didactic teaching is entered upon to any considerable extent, a thorough course of heuristic training must have been gone through in order that a full understanding of method may have been arrived at and the power of using it acquired; scientific habits of mind, scientific ways of working, must become ingrained habits from which it is impossible to escape. As a necessary corollary, subjects must be taught in such an order that those which can be treated heuristically shall be mainly attended to in the first instance.

Largely in consequence of the discussions that have taken place as to the presumed antagonism of religion and science, the public have been led to misconceive the position of the scientific worker and to disregard the moral value of scientific training. It is very important, therefore, to emphasise the fact that experimental work, when properly conducted, affords means of developing character unquestionably superior to any provided by the other subjects in the school curriculum,

mainly because it touches upon daily practice at every point as well as on account of its disciplinary value. This argument is seldom brought sufficiently into prominence and it is difficult, moreover, to recognise its force as long as the teaching is so imperfect as at present. I know of few cases in which the value of science has been so clearly acknowledged from this point of view as it was by Mrs. Fenwick Miller, then a member of the School Board for London, in the course of the discussion, at the Health Exhibition Conference in 1884, on a paper read by Miss Beale on the curriculum of a girls' school. After expressing the opinion that women were specially capable of taking scientific principles and drawing from those scientific principles practical rules for daily conduct and that in the future women would have a special work to do with regard to education, Mrs. Miller made the remarkable statement: "She believed the way they would work it out was chiefly by morals, she meant the practical conduct of daily life; and she believed there would be a development, of which they did not dream, of morals founded upon science, of good conduct based upon reason and upon reasoned facts, such as had never yet been seen and such as they could hardly conceive. She believed that the great work for which the world was waiting was a science from which they could daily draw their life lesson. . . ."

Among the various ways in which, when properly conducted, heuristic experimental studies conduce to the formation of moral and intellectual character and purpose are the following:—

In the first place, interest is excited in common objects and common phenomena and these are gradually studied—not merely talked about. Children are thus

encouraged to look about them — to be properly inquisitive and inquiring.

They learn to use a balance, to weigh and measure not things only but deeds and words also—for whatever is done is done exactly; measurements are made whenever possible and their value as the means of making exact statements is cultivated by use — measuring and weighing, in fact, are so constantly practised as to become ingrained habits.

Habits of observing correctly are acquired. Neatness and care in all work is insisted on. The waste of materials is in every way discouraged and the practice of economy inculcated. The habit of patiently attending to details is acquired.

The power of reasoning from observation is cultivated in every possible way—a logical habit of mind is thus developed. The use and value of evidence becomes obvious. And that nothing may be taken for granted is insisted on. The faculty of reasoned judgment is cultivated.

The power of devising and fitting up apparatus as well as of devising and carrying out experiments is cultivated. Thus handiness is acquired.

Surely a sufficient list of possibilities.

Many practical problems must be solved, however, before suitable studies can be effectively introduced into schools generally and these results secured.

It stands to reason that the instruction can only be properly given by sympathetic cultured teachers capable of engaging in elementary research work; and if the subject be not in the hands of the head of the school, it must nevertheless be accorded the fullest sympathy and not rated inferior to any.

The provision of proper teachers will occasion the

greatest difficulty until our colleges and universities take the requirements of teachers into account. The instruction given at Training Colleges at the present time is as anti-heuristic as it is possible to make it, so that little help can be derived from them. There is no doubt indeed that very special steps must be taken to secure a supply of competent teachers of both sexes.

But that universal bugbear, the time-table, steps in even where the conditions are otherwise favourable. In the early part of the course there is no difficulty in treating the subject like all others; but when experiments involving the use of apparatus come to be made, little can be done in the time devoted to an ordinary lesson.

In all probability the time difficulty will never be properly met unless a radical change in our method of conducting schools be effected: until a new conception of school life is introduced, based on due recognition of the fact that, as Huxley puts it, "the great end of life is not knowledge but action."

Let us then guard our future by introducing into our schools an education calculated to promote action. Results show that our present system has precisely the opposite effect: the majority of scholars stream towards the clerk's desk and sedentary employment—for which their education affords some preparation whilst providing practically none for a life of action. We must not only protest but revolt against and depose those who hold the nation back through want of culture and failure to understand the conditions of the problem. Surely our schools should give an education that is liberal in every sense of the word.

To this end, we must give up a large proportion of the desk work done in schools and instead of enforcing

silence encourage our scholars to enter into rational conversation about the work they are doing. Why is it that our children so seldom talk about their school work? Why is so much trivial conversation indulged in on all hands? Why is so much trivial literature read? Is it not because so little encouragement is given to rational conversation and reading at schools?

When our pupils engage together in the work of discovery and are set to find out things themselves, they will naturally be led to discuss their work together, to exchange views, to ask each other's advice: they will be so interested in their work that they will not fail to talk about it. Nothing could be less rational—less truly preparatory for the work of life—than the system of enforced silence we enjoin; but it is a necessary outcome of didactic class teaching, extravagant indulgence in the use of books and disregard of all tools and weapons other than the pen.

In all schools open in the afternoon, after the midday meal, I would only allow work to be done in the workshop or workroom—a room in which scholars can move about freely and do all kinds of practical work—and several mornings in the week should also be spent there. In schools such as Girls' High Schools, where the practice prevails of giving lessons only in the morning, at least two mornings should be given up to workshop exercises. It would be better in such schools to substitute attendance in the school workshop for some part of the excessive amount of home work exacted. In many schools—country schools especially—I would have little else but such work or equivalent outdoor exercises in the experimental gardens which will, I believe, in the future, be held to be an essential feature of their equipment. Gradually

I would have nearly all class-rooms converted into workrooms or workshops.

The use of the words workroom and workshop is in itself not unimportant—they are good English, I believe. Laboratory—an un-Saxon term—is without significance to English ears in comparison with them; even its pronunciation gives rise to difficulty.

When class teaching is the order of the day, it is easy to exact attention and silence in the workroom by ringing a bell; at other times, teachers would constantly move about, noticing what is being done, criticising and giving brief directions to one group of pupils after another. The system is simply that pursued in many college classes. Young children will work as steadily as their elders, if only they are properly disciplined from the very outset: under almost any conditions if interested in their work. Moreover, when such a system is adopted, an effective punishment will be a few days' banishment from the workroom to the bread-and-water-solitary-confinement atmosphere of the old-fashioned class-room.

Of course it will be said: "But such a scheme is purely "chimerical; it is the dream of an idealist, of a theorist who has "no acquaintance with, nor conception of, practical possibilities." Quite so! But most of my friends who were teachers in schools were good enough to say that the British Association scheme was an impossible one to carry out in practice; and yet a couple of earnest men, without preconceived views but full of common-sense, in the course of half a dozen years succeeded in applying it to a large number of scholars in public elementary schools, which, surely, are sufficiently difficult and unpromising material to deal with. Many teachers in our great public schools,

I know, still hold such a view; but no one expects such schools to reform before the millennium is reached; they are in the toils of our ancient Universities and too fully engaged in classical scholarship to consider what is good for boys generally.

After all it is mainly a question of attitude. The revolution advocated could be effected if only it were seriously entertained; if the matter were considered not from the point of view of the mere student but on the assumption that school training must be regarded as a preparation for the diversified work of life; if the heads of schools and university authorities could only be led to see that it is now necessary to substitute "well-practised" for the expression "well-read" in which it is usual to embody the scholastic ideal of proficiency.

And after all the inevitable must happen. Why cannot we therefore recognise this and in every way hasten the advent of a reform so urgently needed, especially as the thin end of the wedge is already inserted—for among the conclusions formulated in the report of the Technical Education Board of the London County Council to which reference has been made, the following are to be found:—

1. That chemistry is a valuable subject for school teaching but that it should not exclude training in mathematics and languages but should with these form part of a general education.
2. That it should be preceded by an elementary course of physics, to be treated as much as possible as exercises in measurements and practical arithmetic.
3. That the work should be always largely practical.
4. That attention should be paid to the style of the daily record of work, so that it may serve as an education in handwriting, grammar and English composition.

These are sufficiently important recommendations to come from such a Committee and I rejoice to learn that they are already being attended to in many London schools. The last is, if possible, the most important of all, as it clearly contemplates what may well be termed the workshop method of instruction; but drawing should have been included.

At present little attention is given in most schools to handwriting and still less to drawing; handwriting is spoilt rather than improved, as boys and girls are called on to scribble down a vast quantity of notes of lessons dictated to them. In the future this system, let us hope, will give place to a rational one from which hurried writing is abolished and in which every lesson involving writing will be a lesson *in* writing. Also, however much attention may be lavished at school on grammar and composition, when young people leave school, as a rule, they cannot write six lines of plain English descriptive of common objects or events or of anything they themselves do. Many perhaps have learnt to compose plausible essays on the Imagination, the Infallible or the Infinite; but a simple personal report, giving an account of the work carried out under their very eyes or even with their own fingers, is entirely beyond their power.

It is to be hoped that when scientific method is introduced into schools all this will be changed. Let us consider what may be done. An elementary course of physics, treated as much as possible as exercises in measurement and practical arithmetic, is to come first, we are advised. As it is easy to teach children to use figures, to measure and weigh and do simple arithmetic with the aid of a foot-rule, even before they can either read or write, such work will have been begun

in the Kindergarten class; in school it will from the outset take the place of conventional arithmetic. In this work will be included the drawing of lines and simple figures of given dimensions with the aid of T and set squares, *accuracy being insisted on;* and colouring will be resorted to whenever possible. During this period, among other things, leaves of various kinds may be collected, their outline traced or drawn, the venation sketched in and the attempt may even be made to colour such sketches appropriately. The children will also be led to take note of the various materials of common occurrence and to collect specimens of these. As soon as flat figures are understood—the square, oblong, triangle, etc.,—"boxes" or solid figures may be built up from these and the idea of volume early established. Such teaching may be varied in an infinite number of ways. No books will be used but the class will gradually write its own book and so come to understand how books are written: for whenever an object has been properly studied, the teacher, instead of dealing with the scholars individually, will call them to order as a class and by judicious questioning will then elicit all that is needed for the description of the work done. The simplest possible account will be written on the blackboard as the questioning proceeds and at the close of the lesson a senior pupil will copy this with a typewriter; each member of the class will afterwards receive a copy, which will at once be pasted in a book, to be kept for reference and used as a reader.

But as soon as they can write, children will be required themselves to make out lists of the things they have collected and as they systematically study these, to note down their origin, use, colour and other properties obvious to them. And then they

will go on to make experiments to ascertain properties which are not quite obvious. For example, they will be provided with a simple anvil—a common flat-iron turned upside down and supported in a box — and with the aid of this will find out that metals are more or less soft and may be bent and beaten out; that other substances are hard and brittle; and so on. Then, by measuring and weighing regularly shaped blocks, slabs or plates of wood, stone or metal, the differences in density of different stuffs will be discovered. The blocks required for these measurements should, at least in part, be fashioned by the class and there is no reason why girls as well as boys should not do such work, as they would thereby learn much of the nature of the materials in common use and also how to manipulate simple tools. The choice of materials for examination would, however, be largely influenced by locality and the special requirements of the scholars; and girls and boys might often be treated somewhat differently in this respect.

Most children take the greatest interest in finding out what they can about the things that are before their eyes and in common use: if properly led at the outset they soon acquire the habit of helping themselves and of working systematically. By thus selecting some object for study and teaching several subjects at once, so to speak, the time given to the several subjects when taught in distinct lessons may be secured for one lesson, the advantage being that the teacher—or teachers where several combine to take one such composite class — could then find time to pass round the class and criticise the doings of each pupil. To make such teaching effective, the account of the work done should be most carefully written out by

the worker *as the work proceeds*—the dictation of notes by the teacher being regarded as a criminal offence—and no rough notes should be permitted. Such accounts will necessarily be brief and it will be easy for the teacher passing through the class to comprehend quickly what has been done, to underline the mistakes made or to give any necessary explanation. The child would then be at once informed what was wrong and guided in correcting mistakes and in future work. Under the existing system of correcting exercises out of school, not only is a most grievous burden imposed on teachers to the great detriment of their health and always of their efficiency as teachers —for no work is more soul-destroying—but corrections so made never come properly home to the scholars and more often than not are unnoticed. "Take care of the pence and the pounds will take care of themselves" may be translated for school purposes into "Attempt little but let that little be as near perfect as possible." If we can but lay the foundations of method at the outset, great things may be done subsequently. Each day let some simple task be set; insist that this is carried out with scrupulous care and equally carefully recorded in very few lines of clear simple language; whenever possible have illustrative drawings introduced into the record; teach spelling by calling attention to mistakes and requiring these to be corrected by reference to the dictionary—a book which should be in constant use but which is rarely consulted except by those who have grown ashamed of spelling badly; ask for the meanings of certain words used in the record and have various parts of speech selected; even go so far as to require certain words to be translated

into French. As the work proceeds, more and more difficult tasks may be set.

In later work, when the problem stage is reached, a certain order in entering the record of work should always be insisted on. First should come a clear statement of motive — of what is to be attempted, what it is desired to find out. This should be followed by an explanation or justification of the particular form given to the experiment. The why and wherefore being thus made clear, an exact account of what is done should follow; then would come the observations made and the results obtained. The conclusions to be drawn and their bearing on the question under discussion having been most carefully pointed out, the next experiment should be led up to. Throughout, the language should be such as to make the account a personal one, leaving no doubt that something which had been done and witnessed by the writer was described. At present every boy and girl from school, when asked to describe something, will tell *you to do* this or that; or that *if you* do so and so, this and that *will* happen. They simply repeat the words used by their teachers. If training can be given in schools on the lines above indicated, it will be simply invaluable as a preparation for the work of life.

Of course there are many difficulties to be overcome. To teach scientifically will always be more difficult than to teach mechanically. But scientific teaching—not the teaching of science—is imperatively demanded of us and we must find out how to give it. The problem is one that can only be solved by trial—by *heuristic means.*

As showing how such work has been begun in

Elementary Schools, I append (Appendix C) a short account by Mr. Heller of the method Mr. Gordon and he have adopted.

In the introduction to the Headmasters' Syllabus of Instruction in Elementary Science, it is stated, it will be noticed, that the course is intended for all boys and girls *commencing* the study of science. This provision is one of very great importance from an educational point of view, as its acceptance involves the admission that other branches of experimental science cannot be usefully studied until the elements of physics and chemistry have been mastered. This principle, I venture to think, is beyond all question although I fear there are yet many by whom it will not be regarded as established. Let us hope that even these will gradually become convinced as they reflect that practice in measurement is of altogether fundamental importance as the foundation of all scientific procedure; and that as life is one unbroken series of chemical changes the comprehension of the nature of chemical change is also of the utmost value to all.

Parts of the course, however, are undoubtedly of less importance than others to the majority of students and their consideration may well be either postponed or even omitted in favour of extensions of the course in other directions.

The part of the physical course dealing with forces is in this latter category. Although the discovery of the composition of water is of the very highest value as an educational exercise, for most purposes of ordinary life the knowledge that water is a compound of hydrogen and oxygen does not come into account—such knowledge is essential only to the engineer and

other specialists. Therefore, if required to omit any part of the exercises, I should not hesitate to postpone those leading up to the discovery of the composition of water in order to retain all relating to the study of air, fire and earth, the last as typified by chalk. But the comprehension of the nature of food materials and of their function as heat producers, etc., is of the utmost consequence to all; their study should on no account be omitted, if possible, and the composition of water might well be discovered before attempting their examination.

With these limitations, both the series of exercises specified are of extreme value, on account of the discipline they afford as well as of their bearing on matters of everyday importance affecting all alike. But to make the course in any way complete, from the point of view here put forward, it should be supplemented by a series of exercises calculated to excite an interest in plant growth and serving as an introduction to the comprehension of physiological processes. Parenthetically, I may point out that the teaching of physiology proper in schools, except to really advanced pupils, cannot be too strongly deprecated. There is no greater fraud on public credulity practised in schools than that involved in teaching this subject.

It is true that botany has been introduced of late years, more especially into girls' schools, as a means of satisfying the growing popular demand for science; but unfortunately the methods adopted have in too many cases been such as to deprive the teaching of all value as training in scientific method. In fact, the reason for selecting it has frequently been that it could be taught without special apparatus.

A suitable practical course for the purpose here contemplated remains to be devised. Professor Marshall Ward, however, has, at least, taken the first step towards framing a scheme in a syllabus which he originally prepared for the Major Scholarships Committee and which is now included in the programme of the Joint Scholarships Board Examinations. In order that his suggestions may not remain buried in the oblivion of a set of scholarships regulations, I venture to reproduce them here, merely remarking that they seem to me to afford a capable teacher ample material for a series of intensely interesting and instructive heuristic exercises—some of which might be carried out coincidently with the earlier lessons of the elementary science course and others after the problems in the chemical section had been worked through.

The possibility—nay, the need—of adjusting the "science" exercises to meet special and local requirements has been implied if not directly adverted to in the course of this article. It is in this direction that there is so much opportunity for capable teachers to display originality and scope for their talent.

On the human side we all have like requirements although the needs and powers of some extend further than those of others; but as workers and as men and women we are called on to execute varied tasks. These considerations must govern our education and regulate the extent to which it is made alike for all and the extent to which it is diversified.

It is to facilitate such treatment of the subject that it is imperative that the fullest understanding be arrived at of the object in view in introducing practical heuristic studies into schools: that it be

recognised that it is not intended to teach any separate branch of science but that our one purpose is *to give training in scientific method*—as a means of developing faculties at present rarely cultivated but which are essential to the successful performance of all ordinary duties. The general public will be with us instead of against us when this is once understood: ceasing to regard science as an extra, they will welcome it as a means of making school education a more practical preparation than it is at present for the work of life.

But we shall have revolutionised our entire school system in attaining to this end.

It may be desirable that before concluding I should briefly refer to the special provision to be made for experimental work in schools; but rather by way of caution: for on this subject there has been much misunderstanding. Architects knowing nothing of the requirements have too frequently built and at the present time are building school laboratories which are mere slavish copies of those provided in colleges where technical education is given; and most unfortunately, following the same example, some public authorities have declined to recognise laboratories unless provided with sinks innumerable and other elaborate fittings; consequently, not only has great expense been incurred unnecessarily but buildings have been erected altogether unsuitable for the elementary teaching proper in schools. Instead of being put on the common-place footing it should properly occupy, experimental work has therefore necessarily been regarded as a somewhat expensive luxury to introduce into a school. And this will ever continue to be the case until — no doubt in the dim future — governing bodies see that it is greatly to

their advantage to consult those of us who are really capable of advising in such matters. When we are directly appealed to and asked to act as professional advisers and architects are required but to carry into execution schemes arranged with and sanctioned by us, for which we are held primarily responsible, there will be some chance of more economical and practical provision being made. Undoubtedly we too are sure to make mistakes and like doctors we shall differ considerably among ourselves; but we can scarcely fail to display some understanding of our business and to appreciate the relative advantages of the various suggestions made as well as judge of the suitability of the materials proposed. It is useless for architects to go about as they or their representatives often do at present, inspecting laboratory after laboratory, without ever properly grasping the meaning of what they see—consulting one teacher after another, until bewildered by the apparent diversity of opinion with which they meet, they return home in despair and with the assistance of a clerk or draughtsman in the office do the wrong thing for the actual purpose in view.

For work such as is contemplated in this article there must be ample room provided but otherwise there need be no very special arrangements made.

Benches of the kitchen-table type, which need not even be fixed, suffice for nearly all purposes. These must be provided with gas but not with water, one or two long sinks made of wood—elongated washing-tubs—and conveniently situated being sufficient to meet all the requirements of a large class; more are only provocative of endless trouble and untidiness due to constant spilling of water, besides which they engender a wasteful habit of squandering water which

cannot be too severely deprecated: in fact, when the day comes that we shall have taught all children at school how to wash out flasks, test-tubes, etc., properly and with the minimum expenditure of water we shall have introduced a truly scientific procedure into our teaching as well as into household economy. In most schools, together with movable benches such as have been referred to, it will be desirable to provide one or more benches fixed against the wall of the room, having cupboards fixed in the space underneath. Four cupboards may conveniently be constructed in two tiers under the length of bench provided for a single worker; a tray which will slide in and out may with advantage be fitted at the top of each such cupboard. It is quite unnecessary to construct the bench tops of expensive hard wood—any well-seasoned wood will suffice; but whatever the wood, it should be made impervious to water, acid, etc., by ironing in paraffin wax.

As operations involving the production of unhealthy or unpleasant fumes need very rarely be conducted, a single draft closet is sufficient. This may conveniently be fixed behind a long narrow demonstration table placed on a raised platform at one end of the room.

A considerable amount of wall space behind this table should be converted into a blackboard by pinning against it by means of a light wooden framework the specially prepared black canvas which is sold for this purpose. All free wall space should have upright battens affixed to it at regular intervals, to which shelves may be attached wherever necessary and hooks screwed in for hanging up things.

As to apparatus, it should be gradually provided

to meet requirements as they arise; every effort should be made to utilise ordinary articles—medicine and pickle bottles, jam-pots, saucepans, etc.—and to construct apparatus in the workroom; for this latter purpose a carpenter's bench and tools, vice and files, a small lathe, an anvil and even a small forge should, whenever possible, form part of the equipment. Infinite injury is done at the present day, invaluable opportunities of imparting training are lost, by providing everything ready made.

But there are certain articles which *must* be provided — notably centimetre-foot-rules, drawing-boards, T and set squares and balances. The best rule to provide is one made of steel, graduated on one face to millimetres and centimetres on the one edge and to inches on the other; if the inches are subdivided into twelfths, an opportunity is afforded of contrasting decimals with duodecimals. It is advisable to have the rule graduated on its second face into inches and tenths and lower decimals and subdivisions on the one edge, and into inches and 16ths, 32nds, etc., on the other. Such a rule is a perpetual object lesson; its possessor cannot help visualising twelve inches and thirty and a half centimetres as practically equivalent lengths.

But even more fundamentally important, if possible, and altogether indispensable and essential as the primary weapon of heuristic instruction is a proper balance. There is no question that in the future the test of efficiency in a school will be the extent to which suitable balances are provided and used.

"Gott hat alles nach Zahlmass und Gewicht geordnet," are words which ever and again flash before my eyes, recalling the time, over thirty years

ago, when I first saw them written on the wall of the chemical lecture theatre of the University of Leipzig. They express a truth but too rarely realised—a truth which we should seek to impress in principle on all children as the foundation of thrift; the balance, in fact, is an all-powerful, indeed the only instrument which directly enables us to inculcate thrifty habits.

For school use, there are no balances to compare with those made by Becker and Sons, of Rotterdam. That sold by their London agents, Townson and Mercer, of Bishopsgate Street, as No. 66, at a cost of 35s., is the one most to be recommended. Such balances are most conveniently placed on separate small shelves, supported on brackets attached to the walls; when not in use, the balance must always be kept covered either by a light wooden case or by one made of stout cardboard and covered with bookbinder's cloth; this is much better than an immovable glazed case with rising front, as it allows of far greater freedom in use. If properly used and looked after, a balance will last for years. To abandon a few of the worthless text-books with which scholars are now so overburdened will in itself be an advance and if an instrument by the use of which character is necessarily developed be substituted for even a single one of the conventional soul-destroying manuals now in use, we shall have still greater cause to congratulate ourselves.

It will not do to use any kind of balance; the common see-saw suffices for the demonstration of principles and so long as nothing more is in view no other instrument than a see-saw is needed. Nor is the balance to be used merely as a means of obtaining fairly accurate quantitative results. Mr. T. G. Rooper,

one of Her Majesty's inspectors of schools, in giving evidence recently before the Irish Commission on Manual Training in Primary Schools, referred to a balance which he had himself constructed at a cost of 2d., and spoke of the accuracy of the results he had obtained with it. This may well be, but such an instrument never does and never can inspire the respect which is paid to a well-finished sightly instrument by nearly all young children.

The balance, let me again insist, is to be regarded as an instrument of moral culture, to be treated with utmost care and reverence.

But probably when authorities have grasped and applied this fundamental article of the heuristic creed, it will no longer be necessary to urge that scientific method be taught in schools generally: attention will then be paid to the uniform development of all the intellectual faculties, because the, as yet, barely established art of education will have attained to the dignity of a true science.

APPENDIX A

ELEMENTARY SCIENCE

Physics and Chemistry

In preparing the accompanying Syllabus of a course of instruction in Elementary Science the Committee have been actuated by the wish to indicate both to teacher and to examiner what experiments can suitably be performed by beginners.

A large proportion of the time given to the subject should be occupied by the pupils in performing actual measurements themselves; demonstrations are not excluded but should occupy

a secondary place; text-books, however, should be avoided as far as possible.

This Course is intended for all boys and girls commencing the study of science. It represents, in the opinion of the Committee, a suitable commencement for those who continue the subject and indicates the manner in which it may be made of true educational value to those who do not pursue it further.

The first four sections of the Physics Syllabus, involving measurements of length, area, volume and mass, should under any circumstances be taken first; they constitute a course of practical arithmetic and geometry exercises and give infinite opportunity for problems upon ordinary surroundings.

The remaining sections of the Physics may be taken alone or simultaneously with the Chemistry Course and the age at which it should be commenced may be left at the discretion of the teacher.

It is not intended that the teaching should be limited, either to the experiments here given or to the order in which the different subjects are stated. It is hoped that these experiments will be sufficient to indicate the lines on which the teaching should be based and to assist the teacher in inventing others.

ELEMENTARY PHYSICS

The graphic and experimental work in the following Syllabus is intended to serve as an introduction to physical science, bearing in mind its necessary co-ordination with general mathematical work.

With this object in view, it is essential that the instruction should be given in a strictly logical order and the attempt be made to give a proof of each step taken, following as far as possible a proper order of sequence. In the mensuration exercises and, in fact, in carrying out all the work of the Syllabus, no formulæ of any kind should be used.

The exercises are arranged so that pupils may themselves discover the facts and be led to formulate definitions: and this they must be encouraged to do in every possible way, that they may become acquainted with some of the fundamental properties of matter and fundamental natural laws; and that they may be led to understand the reasoning used in deducing definite conclusions and generalisations from the results of their own observations and discoveries.

The apparatus required for the mensuration exercises is tracing-paper, a rule graduated to inches and tenths and to centimetres and millimetres, a pair of compasses, set and T-squares and a protractor. Although the mensuration course may be taken in an ordinary class-room, it is advisable to give such instruction in a laboratory, where the pupil is surrounded with apparatus and is in an atmosphere of measurement. The hydrostatics, heat and part of the mensuration should, as far as possible, be taken in a laboratory suitably fitted; but a large number of the experiments can be done in an ordinary class-room. The fittings for a suitable laboratory are very simple. All that is wanted are tables 8 ft. by 4 ft., with gas laid on to the centre. At the sides of the room and near each table there should be a water supply. For the mensuration, hydrostatics and heat, the apparatus required consists of sets of scales weighing from 500 gm. to 0·1 gm., a metre scale graduated to millimetres, tin cans, tin or copper pots, glass tubing, blocks of wood, cylinders or cubes of iron, copper and other material. The apparatus should be provided in sets, if possible, one set for two pupils working together.

1. *Measurement of Length.*

Books, pens, pencils, floor, walls and all available materials should be measured in English and metric units. The straightness of a line should be tested by means of tracing-paper and comparisons of ruled lines made by means of scales and dividers.

Triangles and other straight-lined figures may be drawn upon paper and their sides measured. Curved lines should be measured by means of threads and by rolling a disc along them; the distance round cylindrical surfaces, such as that of a glass bottle, should be measured by twisting thread round them and the ratio of the diameter of a circle to its circumference discovered.

The use of the plumb bob and of the spirit-level having been explained, the character of perpendicular and inclined lines, squares, parallelograms, etc., should be discovered with their aid.

2. *Measurement of Area.*

UNIT OF AREA.—The square inch and square cm. should be drawn. Areas of squares and oblongs should be found by drawing upon paper and dividing into units, by drawing upon "squared" paper and counting squares or by cutting out in

paper and weighing. The same methods can be adopted for finding the areas of triangles, parallelograms, trapeziums and polygonal figures, care being taken that the areas of the first three are reduced to area of equivalent oblongs, all formulæ being carefully avoided. The principles of land surveying and the use of off-sets in the division of irregular areas into figures already understood should be explained and illustrated with examples to be drawn and worked by the student.

Area of Circle.—Circles and their equivalent figures (equal to $3\frac{1}{7}$ times square on radius) should be drawn upon paper, cut out and weighed; or circular discs of paper may be weighed and compared with weight of unit of area of same paper; or the drawing upon squared paper may be adopted. In this way the relations between area of circles to their diameter should be ascertained.

Surface Area of Solids.—The surface area of common solids, as oblong blocks, cubes, cylinders, prisms, cones, etc., should be determined by wrapping round with paper and afterwards developing and measuring the areas of the paper by methods already used.

3. *Measurement of Volume.*

To gain an idea of their dimensions, single units, viz., 1 c.c. or 1 cub. in. should be cut from soap or wood and a cubic decimetre or litre made from cardboard.

The volumes of rectangular blocks, prisms and cylinders should be measured. The use of burettes and graduated vessels having been learnt, the volumes of irregular solids should be found by placing them in liquid in a graduated vessel.

The volumes of various simple solids should be expressed in terms of the volume of their equivalent prism or cylinder; thus the volume of a cone should be ascertained to be one-third the volume of a cylinder of same base and height and this can be done either by weighing or by use of graduated vessel.

4. *Measurement of Mass.*

Units of mass and weight having been brought under notice, a lever should be constructed from a boxwood rule laid over a fulcrum and its laws discovered by suspending weights at different distances. The use and construction of the balance having been explained, the blocks, etc., previously measured should be weighed and their density found, as well as definite

volumes of water and other liquids measured and weighed. Graphic representations of densities should be constructed with the data thus obtained. Lastly, the construction and use of the spring balance should be studied and the difference between it and the balance made clear.

5. *Measurement of Density.*

Densities and relative densities should be found and compared by weighing blocks or cylinders of different solids (wood and metal), the volumes of which can be calculated or found as above.

A 2 oz. bottle having had a nick filed along the stopper, the weight of water which it contains should be ascertained, hence its volume in c.c. It should then be filled with other liquids and weighed and thus their density discovered. The volume of small solids—as shot, nails, etc.—should be found from the weight of water which they displace.

6. *Measurement of Thrust and of Pressure, of Pull and of Tension. Distinction between Solids, Liquids and Gases.*

Attention should be directed to the elasticity and plasticity of solids by experiments upon india-rubber, steel and copper springs or rods, pieces of lead, putty, cork, etc.

Experiments should be made on the flow of sand, pitch, treacle, water, etc., leading up to the discovery of the horizontal surface of a liquid at rest and to the distinction between solids, liquids and gases and the mobility of particles of gases shown by their diffusion.

Fluid pressure should be expressed as "inches of water" or "lbs. weight per unit area." The pressure of the gas in the laboratory should be measured in inches of water with a U-tube. Water or other liquids and mercury should be poured into different arms of U-tubes having the two arms of different sizes. Pressures at different depths under water should be measured with a U-tube containing mercury. The U-tube should now be used for determination of relative densities of liquid.

Air should be proved to have weight by boiling water in a Florence flask, weighing, closing it while full of steam, allowing air to enter and again weighing. It should be proved, by using an air-pump, that air exerts pressure and the principle of the barometer should be explained. A siphon barometer, with the short limb adjustable, having been constructed, daily observa-

tions should be made and plotted on square paper. Boyle's law should be discovered for pressures greater and less than atmospheric pressure. The action of the syringe, the suction-pump and force-pump should be investigated.

7. *Measurement of the Force which a Liquid exerts upon a body immersed in it.*

A block whose volume is known should be weighed in air and in water; the weight of water displaced should then be found by measurement and shown to be equal to the "up-thrust." This should be done with solids heavier and lighter than water, wholly and partly immersed in different liquids and thus the force exerted on a body immersed in a fluid made clear. The laws of floating bodies should be discovered by using a block of wood made to float at different depths by addition of lead or a test-tube containing a paper scale and shot which is adjusted to cause floating at different depths. These principles should be applied to the determination of densities of solids and liquids and the relation between weight, volume and fraction immersed in the case of floating bodies should be shown to lead up to the use of the hydrometer.

8. *Measurement of Temperature.*

Observations on the melting and boiling points of water having been made, the construction of the thermometer should be explained and the fixed points noted.

Familiarity with the use of the thermometer in its various forms—maximum, minimum, clinical, etc.—should be gained and daily observations of temperature made, and plotted on squared paper.

In order to study radiation, a vessel of water containing a thermometer should be coated with different substances—lamp-black, tin-foil, etc.—and the time taken to cool through various temperatures observed.

In order to study absorption, the thermometer should be allowed to cool while supported in a vessel coated inside with various substances.

Conduction should be illustrated by the melting of wax on bars of different metals of the same size.

9. *Measurement of Quantity of Heat.*

Known weights of water at different temperatures should be mixed, the resultant temperature noted and the units of heat

gained and lost compared and hence the capacity for heat of the calorimeter is found. Different substances having been heated to 100 degrees by placing them in a test-tube in the mouth of a flask containing boiling water, they should be placed in water in the calorimeter, their heat capacity thus measured, and the equivalent mass of water determined directly by pouring in water at 100 degrees C. Pieces of dried ice should be placed in warm water and steam passed into cold water and the discovery made that heat is absorbed in producing changes of state. The terms "specific heat" and "latent heat" should be explained.

10. *Measurement of Vapour Pressure.*

Experiments should be made on evaporation by finding the loss of weight from a dish of water day by day and the daily changes in weight of a bag of seaweed or a flannel roll.

Observations should be made on condensation of vapour, on the distillation of water and of mixed liquids and on the use of the wet and dry bulb thermometer.

11. *Measurement of Force in lbs. or grams weight and their Graphic Representation.*

The relation between tension and extension should be discovered by stretching an india-rubber cord and a spring-balance should be graduated.

12. *Resolution of Forces.*

Resultant and components: Parallelogram of forces. Experiments should be performed with the aid of a board provided with pulleys, having cords passing over them knotted at one end and having weights on the other. The direction of the cords should be marked off on drawing-paper placed behind them. All exercises should be worked practically in this way as well as graphically.

13. *Equilibrium of Three Forces.*

Triangle of forces. Experiments should be performed with the board mentioned in 12, using three weights and cords. The magnitude of the weights may be given or the directions of the cords. Numerous experiments should be performed on triangle of forces, as with model of crane, where jib and tie are fitted with spring balances, two strings attached to balances

and tied to a weight, the angle between the strings being varied, simple roof truss, etc. The extension of this principle to the pull in a cord having a number of weights attached at different points and the two ends fixed to a bench and with spring balances between the weights, should be shown, thus introducing the "funicular polygon."

14. *Equilibrium of Four or more Forces.*

Polygon of forces. This is a natural extension of the last-named principle and is worked experimentally in the same way. The model of the crane is used with the chain dividing the angle between the jib and tie.

15. *Parallel Forces.*

Reaction at support of beams. The principle of the funicular polygon should be applied to finding the resultant of a number of parallel forces or the resolution of a single force into two parallel forces as at the supports of a beam. Experiments to illustrate the first of these can be performed with a lever supported on or by a spring balance and with weights attached at different distances; and as to the second by a lever suspended by spring balances at each end, and with a movable weight. All experiments should be verified by a graphic construction.

16. *Centre of Gravity.*

Experiments should be performed in balancing rods and circular, triangular and irregular plates of wood or cardboard. Triangular plates should be suspended by a string from each corner and the intersection of the strings shown to be the balancing point. Pieces of wood-board shaped to triangles, parallelograms, etc., should be placed on a board and the effect of inclining this ascertained. Similar experiments should be made with oblong blocks of wood, cylinders and cones. In this way the student should discover the position and properties of the centre of gravity.

17. *Principle of Moments, Levers.*

Meaning and use of moment. Numerous experiments can be performed on wood levers, divided along one edge into inches and having a simple movable or fixed knife edge to

form a fulcrum. Weights can be attached by strings. A bell crank lever can be made with a spring balance at end of short arm, the long arm being graduated for weights at different distances from the fulcrum. The student should discover and prove the principle of moments, with varying loads and distances and with the different levers, first by neglecting the weight of levers, and then by considering their weight.

18. *Simple Machines.*

Principle of work. Units of work. Meaning and use of words "agent," "energy," "power," "machine." Simple machines, as pulley blocks (one, two or three sheaves), differential chain pulley, screw jack, wheel and axle, windlass, can be fitted up to permit of raising load by weights (called the power) placed in an axle pan. The velocity ratio of each machine should be found by actually measuring the distance moved by the power and load and this should be done several times and in different ways. The power required to overcome different loads should then be found by experiment and the mechanical advantage and efficiency of the machines should be calculated. The results should be plotted upon squared paper in the form of curves.

ELEMENTARY CHEMISTRY

Synopsis

1. The object of the course of instruction indicated in this Syllabus is to impart, not only information, but chiefly the knowledge of method.

2. It involves the study of:

   Air and nitrogen.
   Combustion and oxygen.
   Hydrogen and water.
   Chalk and lime.
   Carbon and its importance in organic substances.

3. The practical work consists in accurately describing given substances, and in quantitative experiments on the following subjects:—

   (*a*) The alteration in weight of substances on heating.

(*b*) The measurement of the volume and weight of gases given off on dissolving substances in an acid or on heating.

(*c*) The production of crystallised substances and the estimation of water of crystallisation.

(*d*) The weight of carbon dioxide and of water produced by burning organic compounds.

(*e*) Volumetric experiments in alkalimetry without the use of formulæ.

(*f*) The volumetric measurement of chalk in water.

4. All formulæ and equations, all ideas of molecules and atomic weights, are avoided in this course and chemical names are only introduced in proportion as their meaning can be established.

Syllabus

While the main object of the course should be to train students to solve simple problems by experiment—to work accurately and with a clearly defined purpose and to reason from observation—the instruction given should eventually lead them to comprehend the nature of air, water, "fire," earth and food.

1. Candidates should be made familiar with most of the common substances occurring naturally (such as sand, flint and quartz, chalk, limestone and calc spar, clay and slate, gypsum, galena, hæmatite and clay iron ore, iron pyrites, tin stone) and with the various metals and other substances in common use (such as the common acids, soda, salt, alum, whitening, lime, sulphur, sugar, starch, fats, oils, bone, different woods, charcoal, coke, alcohol, turpentine, etc.).

2. They should be able to describe the appearance and other obvious properties of such substances and, in the case of many, to state what they are principally used for and to give some account of their origin; they should know if anything happens to those with which they are most familiar under ordinary conditions in contact with air or water or when burnt and be able to describe what happens in ordinary language, without, however, attempting to give any chemical explanation.

3. They should have determined the relative density of most of the substances mentioned.

4. They should have examined their behaviour with water and other liquids, including acids; and have learnt how substances such as salt, soda and alum can be crystallised from water.

5. Different natural waters should have been evaporated and the presence of dissolved solid matter ascertained and its amount. Purified water should have been prepared by distillation. The appearance of air bubbles on heating water should have been noted and the amount of "air" dissolved in water approximately determined.

6. They should have made simple *quantitative* experiments on the behaviour of typical organic, mineral and metallic substances when burnt or strongly heated.

7. The study of changes such as attend the rusting of iron and the burning of ordinary combustibles should then have been entered on and a series of experiments made whereby they had been led to *discover* that the air is concerned in such changes but not as a whole—that, in fact, it contains an active constituent; the extent to which this constituent is present should have been determined and they should have been led to appreciate the *general nature* of the changes which attend its withdrawal. Attention should have been directed to the character of the products, to the resemblance which many of them bear to earths and to their behaviour towards water, acids, etc. In some cases, *e.g.*, copper and lead, they should have ascertained the extent to which the active constituent of air is fixed when the substance is burnt, thus becoming familiar with the existence of *compound* substances formed from *definite* proportions of substances differing altogether from them in properties.

8. Attention having been called to the production in large quantities of the substances formed on burning various metals (iron scale, copper scale, litharge, red lead, zinc white), the attempt should be made to separate the active constituent of air known to be present in these by strongly heating them, such attempt being based on the previous observation that some earthy substances (*e.g.*, chalk) lose in weight when strongly heated.

9. It having been previously observed that when metals such as iron and zinc dissolve in acids, a gas is given off which burns, this gas should now be studied with the object of finding out what happens when it burns. Having ascertained that it affords a liquid when burnt, they should have compared this liquid

with water—which it resembles in obvious properties—by ascertaining its density, freezing-point and boiling-point. Having thus discovered that water is formed on burning the gas in question, they should have been led to discover that oxygen is also concerned in its formation and to produce it from oxides such as those of lead and copper. They should then have made quantitative experiments from which they could infer the composition of water by weight. The properties of water should have been contrasted with those of its components and the production of heat as a consequence of the association of the two gases and in other cases of association consequent on and attending burning should have been thoroughly grasped—in fact, at this stage, a full general understanding of the nature of combustion should have been arrived at and the evolution of a definite amount of heat, as a consequence of the formation of a definite amount of the compound substance, should have been made thoroughly clear to them.

10. Passing next to the study of earthy substances, chalk should have been chosen for examination, on account of its resemblance to substances formed on burning metals, such as zinc, etc., in air. It should have been carefully contrasted with lime, to bring out the fact that it is profoundly changed when burnt. The conversion into lime should have been studied quantitatively. Its behaviour towards acids should then have been examined and the discovery made that the gas which escapes is equal in amount to the loss which it suffers when burnt to lime; this being suggestive of the conclusion that "chalk-stuff" is composed of "lime-stuff" and the gas in question, experiments should have been made to reproduce chalk-stuff from lime-stuff and the gas. The discovery of the composition of chalk-stuff in this manner should also involve the accidental discovery of the formation of chalk-stuff on exposure of lime-water to air and the consequent discovery of the presence of "chalk-stuff gas" in air.

Similar experiments should have been made with washing-soda, involving the discovery that it contains water of crystallisation and that it resembles chalk-stuff in composition. The definite manner in which it acts on acids should have been established by titration experiments, its use in softening water should also be referred to and examined into and experiments made to determine hardness by soap solution.

11. Attention should then have been directed to the study

of common organic materials—sugar, starch, gluten (from flour) and white of egg being taken as typical examples. The presence of "coal-stuff" or carbon in all of these having been inferred from their behaviour when incompletely burnt, the presence of hydrogen and oxygen will be indicated by their yielding water when destructively distilled.

12. The formation, on burning carbon of the gas previously obtained from chalk and found in the air having been discovered by experiments in which carbon had been burnt in oxygen and the product compared with the gases previously studied, its production from carbonaceous substances generally should have been observed. The composition of the gas should have been ascertained. The conversion of sugar entirely into this gas and water on combustion having been demonstrated, albumenoid substances should have been burnt and the discovery made of the presence in them of nitrogen in addition.

EXPERIMENTS TO BE CARRIED OUT

1, 2, and 3. Examination of common substances by the eye and by simple tests requiring nothing more than very ordinary appliances—*e.g.*, scratching, powdering or hammering, wetting with water—and determination of simple physical constants, as density, boiling-point, etc. (Great importance should be attached by the examiner to ability to satisfactorily examine and describe substances—and this should be tested practically.)

4. Behaviour of common substances towards common liquids, *e.g.* water, spirit, turpentine, dilute acids. (Such experiments may well be carried out with drops of liquid on watch-glasses.)

5. Discovery of dissolved matter (solid) in natural waters. Distillation of water and other liquids. Collection of air given off on boiling water (by filling a two-gallon tin can provided with a delivery tube with water, and heating, etc.).

6. Effect of heat on substances generally. (Common substances, *other than metals*, should be heated on platinum foil. Pieces of metals may be held in a flame or supported on charcoal, and organic substances may be held by a platinum wire.) The amount of ashes given by a few combustible organic substances —a dried vegetable, wheat, dried meat and bone. Substances such as sand, chalk, etc., should be heated strongly in porcelain

crucibles and any change in weight ascertained. Weighed quantities of several metals—*e.g.* copper, lead and silver—should be heated in clay dishes (such as are made by Morgan and Co., of Battersea) if possible, in a muffle furnace, or over a blow-pipe flame and any alteration in weight, appearance, etc., noted.

7. Discovery that air is concerned in common changes, such as the rusting of iron, combustion, etc., and that its activity is due to one constituent. The proposal having been made to study the rusting of iron as an instance of a change of very common occurrence, a careful comparison should be made between iron and iron rust, including the determination of their relative densities, as it is noteworthy that rust is apparently a light substance in comparison with iron. It being found that rust is considerably less dense than iron, in answer to the question, What does this suggest? it may be said that perhaps the iron loses something in rusting. The following are then appropriate experiments :—

a. A weighed quantity of iron borings or turnings or small French nails is wetted, allowed to rust, dried and weighed ; the mass is then broken up, wetted, exposed, dried and again weighed, this being done several times.

b. Clean French nails are corked up in a medicine bottle full of water.

c. A muslin bag full of iron borings is exposed in air over water, this experiment being made several times.

d. Iron (coarse powder or bright fine wire) is strongly heated in a tube through which air is passed, and any alteration in weight ascertained.

e. Fine copper wire is similarly treated, a comparison experiment being made in which the copper is heated inside a sealed tube.

f. A candle is burnt in air over water, then a jet of gas, a spirit or petroleum lamp, sulphur and phosphorus.

g. Phosphorus is burnt on a tile under a shade.

h. A small piece of carefully dried phosphorus is burnt inside a dry pear-shaped flask full of air shut in by a rubber stopper ; the flask is subsequently opened under water and the amount of water which enters is measured and compared with that which the flask will hold. The results of several such experiments are compared. By weighing the flask both before and after burning the

phosphorus proof is obtained that the heat which escapes is not material.

i. A small stick of phosphorus is exposed in air over water. Iron turnings are subsequently exposed in the residual air from this experiment and phosphorus in like manner in the residual air from experiment *e*.

k. Phosphorus is placed near to the end of a short tube packed with asbestos; the tube having been weighed, air is slowly drawn through the tube and the phosphorus fired; care must be taken to prevent the escape of fume. When the phosphorus is burnt out the tube is allowed to cool and is then weighed.

N.B.—The tube should be about $\frac{3}{8}$ in. wide and 6 in. long, drawn out at one end. Fibrous asbestos is carefully pushed in to form a respirator, then a piece of phosphorus and then a $\frac{1}{2}$ in. plug of asbestos. The air is sucked through by means of an aspirator with a screw clip and it is well to insert a wash-bottle between it and the tube.

l. The gas left on allowing iron to rust in air is passed over heated copper.

m. The extent to which finely divided copper increases in weight when fully burnt is determined.

8. The various solids obtained by burning metals (magnesium, zinc, lead, iron), in air—their appearance—their production on a large scale—special behaviour of lead; litharge and red lead, how produced and converted into each other; their behaviour when heated strongly tested by the balance; separation of gas on heating red lead; discovery that this gas supports combustion and that it acts on copper as air does. Reproduction of air on mixing this active gas with the inactive gas (nitrogen) left on exposure of iron in air. Formation of an acid solution when the solid formed on burning phosphorus is dissolved in water—explanation of the name oxygen. Preparation of oxygen from potassium chlorate; combustion of various substances in it.

9. Dissolution of magnesium, zinc and iron by diluted muriatic acid or oil of vitriol—the amount of gas given off on dissolving known weights of magnesium and zinc—the amount of zinc dissolved by a known weight of acid—the amount of salt formed. Combustion of the gas—the formation of a condensible product of combustion—collection of the liquid (the gas may be

burnt from a small clay-pipe jet close underneath a globular flask or retort, through which cold water is slowly circulated, so arranged that as the water condenses on the flask it drops off into a small beaker)—comparison of its properties with those of water (*i.e.*, melting-point of solid into which it is converted by freezing and its boiling-point) and its consequent identification as water. Hence the name hydrogen. Combustibility of hydrogen in oxygen but not in nitrogen—withdrawal of oxygen from red lead and copper oxide by hydrogen and formation of water—the amount of water formed from a given weight of copper oxide. The obvious properties of water and of the other oxides studied in comparison with those of their constituents. The explanation of combustion afforded by the foregoing experiments.

10. Comparison of chalk (whitening) with lime—slaking of lime—determination of the increase in weight—solubility of chalk and lime; preparation of lime-water. Loss in weight when chalk is strongly heated—quantities of about a gram may without difficulty be "burnt" in a small porcelain crucible over a good Fletcher burner and still more easily over a blow-pipe flame—a French petroleum blow-pipe burner is sold by Townson and Mercer which is admirably adapted for this experiment—or in a muffle. Action of acids on chalk—the gas incombustible—measurement of the amount given off—comparison of its density with that of hydrogen, oxygen and nitrogen—determination of the weight given off on dissolving chalk in acids. Exposure of lime in atmosphere of gas from chalk and acid—its reconversion into chalk-stuff established by the behaviour of the product to acids, the change in weight which attends the conversion and by the behaviour of the product on ignition. Examination of the solid formed on exposing a considerable quantity of lime-water to the air—*e.g.*, its behaviour towards acids, determination of the extent to which it loses on ignition and of the amount of gas evolved on dissolving it.

Examination of washing-soda—conversion of the clear crystal into a white powder—the loss in weight attending this change—reconversion of the white powder into clear crystals by crystallisation from water—separation of liquid from the crystals by distillation and its identification as water.

Action of acids on soda—examination and identification of the gas—the amount given off—titration of soda solution by acid solutions and discovery of the definite character of the

action—separation of product from solution by crystallisation—the weight of product formed. Production of chalk-stuff on adding soda solution to lime-water or to solution prepared from chalk and an acid proved by carefully comparing the product with chalk-stuff. Presence of chalk in natural waters—its deposition on boiling—effect of adding soap solution to lime-water—measurement of the amount of soap solution required to produce a permanent lather in distilled water and natural waters before and after boiling.

11. Examination of vegetable and animal food materials, as indicated in syllabus—separation of liquid by carefully heating sugar, etc., in test-tube provided with delivery tube and its identification as water. Combustion of carbon and of (*a*) paraffin, (*b*) sugar, as examples of compounds of carbon and hydrogen and of carbon, hydrogen and oxygen—proof that only water and carbon dioxide are formed on burning sugar with copper oxide in a tube from which the air has been displaced by carbon dioxide having been given, the production of nitrogen on burning animal matter will be easily made clear.

APPENDIX B

BOTANY

The questions set will be based on the assumption that the main object of the instruction has been to lead students to find out by their own observation the most important obvious facts relating to the nature and growth of plants and to treat their study as that of living objects.

Introductory Course

1. Students should be led to take particular notice of the commoner herbs, shrubs and trees, which they may have the opportunity of seeing and to describe them in ordinary language.

2. They should be induced to collect leaves and to carefully compare their shape, colour, markings and other characters, to measure them and trace their outline on paper, as well as make coloured drawings of them. The different ways in which leaves are attached, the scars left on falling and the buds in the axils

should also be noted. (Dried specimens of different leaves should be mounted in the note-books.)

3. They should be led to note in a diary kept for the purpose when different plants, shrubs and trees put forth and lose their leaves and when flowering takes place.

4. Whenever possible they should note the situation in which different plants and trees grow; also the influence of situation on growth and time of flowering and the existence of evergreens as distinct from not evergreens.

5. *In the case of trees* they should be led to note the great difference in shape, due to the different arrangement of the branches, especially evident when they are without leaves, which makes trees good objects of study in the winter. The barks of different trees should be noticed and compared. (Such instruction is much facilitated by showing photographs and lantern slides of common trees; and children may with great advantage be led to illustrate the descriptions in their note-books by blue prints which they have themselves made from paper negatives.)

6. A number of stems should be examined and the leaf scars and nodes noted, as also the difference in the length of the internodes.

7. The parts of a big bud such as that of the horse-chestnut having been made out, the presence in a bulb (hyacinth) of essentially similar parts should be noticed; and it should be recognised that in tubers such as that of the potato the eyes are the buds. The gradual growth of buds as also of the hyacinth and potato should be watched, in order that the resemblance they bear to each other may be discovered.

8. Attention should be directed to the use made of different kinds of wood—and by cutting pieces of such wood with a pocket-knife, boring holes in them, weighing and measuring regular slabs and so ascertaining the weights per cubic centimetre or cubic inch (use may be made of such data in framing arithmetical exercises, *e.g.*, calculations of the weight of planks of different sizes, floors, etc.) and carefully describing their appearance; students should be led to correlate their use for certain purposes with their properties. (It should be noted that herbaceous flowering plants have wood too, although very little; and that wood consists of nothing but pipes such as are met with in veins of leaves, stems, etc.)

9. Weighed quantities of sawdust or chips from different

wood should be dried in the water-oven and the loss on drying ascertained and should then be burnt and the amount of ashes noted (this would be part of the Chemistry course).

10. The effect on the growth of trees and other plants of crowding together should be noted whenever opportunity offers in the case of trees and should be ascertained by trial with some suitable garden plant. Students should be led to inquire why this is the case.

11. *In the case of leaves* students should be led to realise that the leaf is but the flattened-out growth of the stem, as is especially evident in the lettuce and cabbage.

12. That however varied in shape, leaves are ordinarily flat, thin, veined and green—they should be led to inquire why.

13. That the veins act partly as supports, as do the ribs of an umbrella, which is particularly obvious when skeleton leaves are prepared with the aid of a solution of bleaching-powder.

14. That the veins also act as pipes.

15. That the leaves are built up of cells.

16. That there are openings (stomata) in the surface layer of cells leading into the interior of the leaf. (The injection of fluid or the expulsion of air may be observed by dipping leaves —*Ranunculus ficaria* or an onion leaf—into water and blowing or sucking.)

(Conclusions 14, 15 and 16 should be arrived at by students from their own observation with a microscope or hand lens.)

17. Fresh leaves should be put on the balance and counterpoised and the fact demonstrated that they grow lighter as water is lost; they should also be dried in the water-oven and the amount of water lost ascertained; the dried leaves should then be burnt and the amount of ashes they yield ascertained.

18. *By observing roots*, they should be led to see that they offer a large surface and many points of attachment, this being enforced by setting them to measure and estimate the total length of the roots of some common plant, such as geranium.

19. That the roots are covered with root hairs, which still further increase their power of coming into contact with the moist soil in every direction. By experiments with cuttings (geranium, etc.,) they should be led to discover that until new roots are formed, the cuttings cannot become plants capable of independent life.

20. That roots are cylindrical—firm and slippery at their tips and that they therefore penetrate easily.

21. That the tips are provided with protective caps, which gives them still greater power of penetration.

22. *By observing a few common flowers*, they should be led to notice the difference between corresponding parts.

23. To realise that the calyx has a protective office.

24. That the corolla plays the part of a coloured banner, being attractive.

25. That all stamens bear pollen.

26. That although pollen is often found on the pistil, it does not bear pollen and the seeds develop from within it.

27. A considerable number of common fruits and seeds should be studied (such as acorn, chestnut, bean, pea, wheat, barley, oat, tropæolum, onion, date, cucumber, castor-oil, sunflower); their appearance should be noted and described and their average weights ascertained.

Vegetable Physiology

1. Germination.—Why do seeds "germinate" when sown in the ground; in what way are the conditions under which such seeds are placed different from those under which unsown seeds are placed? The answer to such a question would suggest that the following experiments should be made to solve this problem; that four parcels of seed, barley or mustard, for example, should be kept (in a sufficiently warm place) close together, one of them (*a*) dry and exposed to light, another (*b*) also dry but covered over so as to be in the dark; the remaining two, after thorough soaking in water, to be kept on muslin just above water, (*c*) being exposed to light, (*d*) being covered over.

2. Why do seeds germinate quickly at one time of the year and not at another? Comparative experiments on germination should be made in and out of doors in cold weather to answer such a question as this. Experiments should also be made, if possible, at somewhat high temperatures, so that it might be discovered that there is an upper limit of temperature as well as a lower one.

3. The shrunken appearance of germinated seeds having been noted, a weighed quantity of seed (barley) should be allowed to germinate until the young plant is an inch or so high and the germinated grain should then be dried in the water-oven and weighed. Similar experiments might be made with potato tubers.

4. The result should suggest the question—What has become of a portion of the seed? The student would know from the chemistry lessons that seeds consist of carbonaceous combustible matter and that in changes which take place in the air the air is very frequently concerned and would, therefore, be prepared to expect the formation of the gas which is produced on burning carbonaceous matter. An experiment should therefore be made to ascertain if such is the case.

5. A further experiment should then be made in which seeds are allowed to germinate in air confined over water, in order to ascertain if air is concerned in germination.

6. The results of 4 and 5 should serve to suggest the question whether, as in burning carbonaceous materials, heat is not given out during germination. To test this a handful of steeped barley should be allowed to germinate (in a wooden box provided with a muslin bottom so as to allow air to penetrate), a clinical thermometer being placed within the mass and another near to the box to indicate the external temperature.

7. Attention should be directed to the difference in taste between germinated and ungerminated barley, and to the change which a potato undergoes during germination, and the question asked—what the difference suggested.

8. An account should be given of the production of malt on a large scale, and of the use made of it by the brewer. The changes which go on should then be investigated.

9. Weighed quantities of finely crushed barley and malt should be dried in the water-oven and the amount of water lost ascertained. Weighed quantities of the same materials should be mixed, each with about twenty times its weight of water; the mixtures should be frequently shaken or stirred and after several hours should be filtered. After once washing the residues they should be dried and weighed.

10. The question would then arise—What was dissolved? The presence of starch in raw grain should then be discovered by kneading flour in water and the starch should be separated and its conversion into a paste and its behaviour with iodine observed.

11. The taste of the extract from the malt having been noted, its behaviour to an alkaline cupric solution in comparison with that of starch should be studied.

12. Attention should then be directed to the fact that the brewer at first digests the malt with warm water and only

boils the liquid after some time; and this should suggest the experiment of trying the effect of boiling water on the malt. It would thus be discovered that the conversion of the starch into sugar takes place to a large extent gradually, on digesting the malt with water; that therefore something is formed during germination which makes starch soluble by converting it into sugar. This should suggest the experiment of adding some cold water malt extract to a thick starch paste or potato mash and noting the gradual change in the behaviour of the mixture to iodine. A similar experiment might then be made, using a portion of the same malt extract but boiling it before mixing it with a starch.

13. Growth of Plants.—Attention having been directed to the size of a plant in comparison with that of the seed from which it grew and to the production of many seeds from one, the changes which attend growth should be followed. The growth of several quick-growing common plants (cress, tropæolum, barley, pea) should be carefully watched and measurements made and every detail recorded. Finally the weight of produce—of root, stem and stalk, leaf and seed—should be ascertained, then the weight of dry matter and lastly the amount of ashes. (A careful distinction should be made between "growth" and "nutrition"; the seedling grows in the dark and at the end weighs less than the original seed, whilst a leaf may cease to grow and yet be capable of providing good substance for nutrition long afterwards.

14. Then the question would arise—Whence does the increase come? It is easy to understand that the mineral matter (obtained as ashes on burning vegetable matter) comes from the soil; but does the combustible carbonaceous matter? Does the soil contain carbonaceous matter? Experiment shows that it does. Is this necessary, however, to the growth of plants? Experiments are therefore made to grow plants in water and wet sand free from carbonaceous matter.

15. The results suggest that the carbon may be derived from the air which is known to contain the gas formed on burning carbonaceous matter. Experiments to confirm this conclusion should be made.

16. Attention has been called to the recognised importance of light to plants, the effect of light should be studied by observing the difference between portions of plants exposed to light and portions protected from light, as in the case of celery,

endive, etc., and experiments should be made. In like manner the difference between the growth of the hyacinth and potato in the dark and in the light should be studied.

17. The presence of starch in leaves having been demonstrated, the influence of light on its formation may be studied by covering up portions of leaves.

18. Experiments to test the connection between the formation of starch and the presence of carbon dioxide may be made by growing plants in vessels containing and free from this gas and ascertaining whether starch is found. The evolution of oxygen should also be demonstrated.

19. Special experiments should be made to show the importance of water to plants and the importance of salts should be illustrated by a few simple sand-culture experiments.

20. *Yeast, moulds and fungi.* Attention having been directed to the use made of yeast by brewers, its actions on sugar solutions should be studied. Its mode of growth should also be investigated and the importance of certain food materials, including salts, should be fully recognised. Moulds and fungi should also be examined, so that a *general* idea of their nature, of the conditions under which they can live and of the *general* character of the effects they produce may be gained. Their destruction ("sterilisation") by heat should be studied and the application of knowledge so gained to household economy (preservation of food) should be insisted on.

By experiments such as suggested the student should have been led to realise that the plant is *alive*, inasmuch as (*a*) it respires oxygen, (*b*) it feeds, (*c*) it grows, (*d*) it moves (apparent on watching tendrils and coiling of nasturtium petioles), (*e*) it responds to stimuli (as shown by heliotropic and geotropic movements and the behaviour of the sensitive plant) and (*f*) reproduces its kind through seeds.

At the close of such a course, moreover, there would be full opportunity of making clear the cycle of change from the mineral to the organic and back to the mineral, through which the study of plant-life carries us; of their dependence on the sun's energy; and hence of the important office they hold in the economy of nature in handing on the sun's energy.

21. In order to lay the foundation for the future study of systematic botany—to encourage the systematic comparison of likenesses and differences, to familiarise students with the relative values of the differences which are manifest in com-

paring plants and to lead them to understand how a short summary of the characteristic features of a family or group of related plants may be given—students should be led to compare flowers—such, for example, as the buttercup, primrose and willow and to point out in what respects they are alike and in what other they are different. They should then, in like manner, be led to examine and compare other typical flowers—such as the wallflower, laburnum, hedge-parsley, dead-nettle, foxglove, dandelion, daisy, hyacinth, orchid, grass.

APPENDIX C

The Method adopted by Messrs. Gordon and Heller in giving Instruction in Elementary Schools

The demonstrator usually made one visit to a school per fortnight and gave one lesson of three-quarters of an hour duration to each of Standards V, VI and VII, or to whatever Standards there were in the school.

The schools visited may be divided into two classes: first, those in which the assistant teachers had been through a course of training at Berners Street; secondly, those in which the teachers were beginning the subject (Course 4) without previous knowledge of the methods to be used.

In the case of those of the former class the demonstrator was free to teach the scholars alone, without considering the class teacher. The monitors of the class usually had charge of and were responsible for keeping the apparatus clean and in order. This was stored in a specially designed lecture table and cupboard combined, fitted with lead sinks and draining-boards, divided drawers, etc., which cost nearly £10; in many cases, however, such a table was not provided and the apparatus was kept in ordinary stock cupboards, the experimenting-table being improvised by placing a blackboard across two dual desks. In many cases a hinged flap table folding down against the wall was found most convenient for experimental work by the scholars.

The demonstrator usually spent a few minutes questioning the class as to the work accomplished during the previous fortnight and dealt with the difficulties that had occurred, taking care to emphasise the exact position the experiments already

made had left the scholars in; he then invited suggestions as to what would be the next point to elucidate. Very good suggestions were often made but as a rule the class had to be led to the consideration of the next question to be answered. As soon as it was clearly understood what was to be the particular object of inquiry, two or four boys would get the apparatus out, fit it up and make the necessary weighings. Perhaps other boys would carry through the experiment to the finish. There was seldom any necessity for the demonstrator to handle the apparatus at all and the fact that the demonstration experiments were performed by the boys themselves ensured the closest attention of their fellows. A living interest in what was going on and a condition of enthusiasm was thus aroused, which was reflected in the whole subsequent work of the class. Between the demonstrator's fortnightly visits there were, as a rule, three intermediate lessons, which were utilised in repeating the last lesson, for back work and in writing up notes; advantage was often taken of writing lessons and composition lessons for note-book work.

In many schools one or two experiments were kept always going on a table in a corner of the room and a few boys—usually not more than four—were always engaged at experimental work, so that in the course of the fortnight every boy in the class would have performed the chief experiments connected with that portion of the work under consideration.

In the second class of school, in the case of a teacher unfamiliar with the work who was, perhaps, at first not willing to take the extra trouble involved in keeping the boys at experimental work, it often happened that the class lost interest and results were unsatisfactory.

Apparatus was supplied to the school at the beginning of the year's work, everything that was required for the work being provided and due allowance made for breakages. Did the occasion arise, apparatus was loaned from the central laboratory to schools likely to use it with advantage, so that work was never allowed to stand still for want of apparatus.

At annual inspections sufficient additional apparatus was sent to schools to enable fifty boys to be at work at once.

XVI

SUGGESTIONS FOR A COURSE OF ELEMENTARY INSTRUCTION IN PHYSICAL SCIENCE

ALTHOUGH the Committee is ostensibly charged to report as to methods of teaching *chemistry*, chemistry pure and simple is not what is generally required in schools: therefore the Committee must be prepared to take into consideration and make recommendations for a course of instruction, preliminary to the natural science course proper, which in their opinion affords the most suitable and efficient preparation for later natural science studies.

After the most careful consideration of the question during at least ten years past; after long holding the opinion that chemistry as usually understood is not the most suitable science subject for school purposes: I am now of opinion that a course which is mainly chemical is not only the best but also the only one possible if we are to secure all the objects aimed at in introducing science teaching into schools. Those objects are essentially: to train boys and girls to use their brains; to train their intelligence; to make them observing and reasoning beings, accurate observers and accurate thinkers; to teach them to experiment—and that, too, always with an object—more frequently than

not with what may be termed a logical object—not for mere descriptive purposes; to gradually inculcate the power of "doing," on which Charles Kingsley has laid so much stress and which undoubtedly is the main factor of success in life. It can scarcely be gainsaid that, through chemistry more than through any other branch of natural science, it is possible to give precisely that kind of "practical" training so requisite at the present day, because the student is able to ascertain *by experiment* what are the exact facts and thus to arrive independently at an explanation, whereas in the case of other sciences, more often than not, the explanation, of necessity, has to be given by the teacher.

Chemistry as usually taught loses greatly in educational value because pupils are told, more often than not, that "such and such *is* the case," instead of being taught *how it has been found out* that such is the case; indeed, that which has to be proved is usually taken for granted. Practical chemistry has hitherto, as a rule, been interpreted to mean the preparation of a few gases, etc., and the analysis of simple salts. Much useful information may be and is occasionally imparted during the performance of exercises of this kind but the tendency undoubtedly is for analysis to degenerate into a mechanical drill; and looking at the question from the practical point of view and considering what is the general outcome of such teaching, probably we are bound to agree that the results thus far obtained are usually unsatisfactory. The difficulty, however, is to devise a course sufficiently simple in conception the cost of which is not too great when it is carried into practice; but with respect to this item of cost the Committee has to make clear to parents and teachers

the claim of natural science to a fair and proportionate share of the total expenditure, which certainly has never yet been granted to it. By the introduction of such studies into the school course, a set of faculties are trained which it is all-important to develop but which hitherto have been allowed to remain dormant, if not to atrophy, through neglect—which, all competent authorities admit, cannot possibly be developed by any amount of attention to literary and mathematical studies. It is often not sufficiently clearly stated or understood that the advocates of natural science studies have no desire to displace any of the traditional subjects from the school course; that all that they ask for is a fair share of the child's time, attention and brains—a share proportionate to the effect which such studies can demonstrably produce in developing the mental faculties of the individual: that, in fact, natural science claims to co-operate and in no sense puts in an appearance as a rival.

STAGE I.—*Lessons on Common and Familiar Objects*

The first stage of instruction must be one of simple object lessons but these should have an intimate relation to the child's surroundings and should be made the pegs on which to hang many a tale. Probably the most satisfactory and practical mode of commencing is to get children to draw up lists of familiar and common objects under various heads, such as

Natural objects.

Things used in building construction.

Things from which household furniture is made or which are in daily use.

Things used as clothing.

Food materials.

The children should be induced to describe these from observation, as far as possible; to classify them according to their origin into mineral and animal and vegetable or organic; and occasion should be taken at this stage to give by means of reading lessons and demonstrations as much information as possible about the different things, their origin, how made and their uses. It is obvious that in this way a great deal of geography and natural history (*Naturkunde*) might be taught in an attractive manner. Geikie's *Science Primer on Physical Geography* is the type of book which may be worked through with great advantage at this stage.

STAGE II.—*Lessons in Measurement*

This stage should be entered upon as soon as children have learnt the simple rules of arithmetic and are able to add, subtract, multiply and divide—and to use decimals.

Lineal measurements may be first made, using both an English footrule with the inch subdivided in various ways and a metric rule subdivided into millimetres. In this way the relation of the two scales is soon insensibly learnt.

Measurements of rectangular figures and the calculation of their areas may then be made.

After this the use of the balance may be taught and the relation between the English and French systems may be learnt by weighing the same objects with the two kinds of weights. Use may then be made of the balance in determining the areas of irregular figures by cutting out rectangular and

irregular figures from the same cardboard or thin sheet metal and weighing these, etc.

Solid figures are next studied: a number of cubes made from the same wood having been measured, their volumes are then calculated and the results thus obtained are compared with those which are obtained on weighing the cubes. The dimensions and weights of cubes made from different woods or other materials are then ascertained and thus it is observed that different materials differ in *density*. The study of the *relative density* of things generally is then entered upon. The ordinary method is easily learnt and used by children, a suitable bottle being provided by filing a nick down the stopper of a common two-ounce narrow-mouth bottle; it may then be shown that the same results are obtained by the hydrostatic method of weighing in air and water and it is not difficult to lead children to understand this latter method after they have determined the heights of balancing columns of liquids such as turpentine, water and saturated brine, of which they have previously ascertained the relative density. These hydrostatic experiments are of value at a later stage in considering the effects of atmospheric pressure.

By determining the dimensions of a cube and the weight of the water which it will displace, an opportunity is afforded to point out that if the results are expressed in cubic centimetres and grams respectively, there is a practical agreement between the numbers and hence, to explain the origin of the metric system of weights and the relationship between its measures and weights; the irrationality of the English system may then be explained.

The relative densities of a large number of common

substances having been ascertained, the results may be tabulated and then the value of the data as criteria may be insisted on; as an illustration of their value, quartz, flint, sand and gravel pebbles may be selected: the children having determined their relative densities, the agreement between the results may be pointed out and the identity of the material explained. By drawing perpendiculars corresponding in height to the densities of various substances, a graphic representation is obtained which serves to bring out the value of the graphic method of representation.

A very valuable exercise to introduce at this stage is based on the well-known fact that in certain conditions of the atmosphere things appear moist: a muslin bag full of seaweed may be hung up under cover but freely exposed and may then be weighed daily at a given time; simultaneously the state of the weather, direction of the wind, the height of the barometer and the state of the wet and dry bulb thermometer may be noted; on tabulating the results, especially if the graphic method be employed, the variations and their relationship will be noticeable.

Familiarity with the thermometer having thus been gained this instrument may be used to examine melting ice and boiling water; the construction of both the Centigrade and Fahrenheit thermometers may then be explained and the effect of heat on bodies made clear. The density of ice and of water at various temperatures may then be determined, a Sprengel tube—which is easily made—being used for warm water; the bursting of pipes in winter, the formation of ice on the surface of water, etc., may then be explained. Afterwards, simple determinations of the heat capacity of a few metals, etc. and of the latent heat of water and steam

may be made in accordance with the directions given in a book such as Worthington's *Practical Physics*.

STAGE III.—*Studies of the Effect of Heat on things in general; of their behaviour when burnt*

As it is a matter of common observation that heat alters most things, the effects of heat on things in general should be studied; in the first instance qualitatively but as early as possible, subsequently, quantitatively. Bits of the common metals may be heated in the bowl of an ordinary clay pipe plunged into a clear place in any ordinary fire or in such a pipe or a small iron spoon over a gas flame. The difference in fusibility is at once apparent. In the case of metals like iron and copper it is noticeable that although fusion does not take place, a superficial change is produced; the gradual formation of a skin on the surface of fused lead and tin is also easily perceived. Observations like this become of great importance at a later stage and indeed serve to suggest further experiments: this is a point of special importance. From the beginning of this stage great attention should be paid to inculcating habits of correct observation; the effect should first be recorded by the pupil, the notes should then be discussed and their incompleteness pointed out and they should afterwards be rewritten. The fusibility of substances which are not affected when heated in the tobacco-pipe may be tested by heating them with a Fletcher gas blow-pipe on charcoal; and by heating little bits of wire or foil in such a flame it is easy for children to discover the changes which metals undergo when burnt,

especially in cases such as that of zinc or copper or iron.

The further study of the effect of heat should be quantitative and may well commence with water. It being observed that water disappears on heating, water may be put into a clock glass or glass dish placed on a water-bath (small saucepan); it evaporates and it is then observed that something is left. A known quantity of water by weight or volume is therefore evaporated and the residue weighed. This leads to the discovery that water contains something in solution. The question then naturally arises, What about the water that escapes? so the steam is condensed and the distilled water evaporated. The conception of pure water is thus acquired. An experiment or two on dissolution—using salt and sugar—may then be introduced, a water-oven or even an air-oven (a small Fletcher oven) kept at a known temperature being used and the residue dried until the weight is constant. Rain- and sea-water may next be examined; the results afford an opportunity of explaining the origin of rain and of accounting for the presence of such a large quantity of dissolved matter in sea-water. Then the various common food materials may be systematically studied, commencing with milk; they should first be dried in the oven, then carbonised and the amount of char determined, then burnt and the percentage of ashes determined. A small platinum dish, 15 to 20 grams in weight, is required for these experiments; a gas muffle furnace is of the greatest use in burning the char and in oxidising metals. In addition to the discipline afforded by such experiments, a large amount of valuable information is acquired and the all-important fact is established that food materials generally are

combustible substances. Afterwards mineral substances are examined in a similar manner, such as sand, clay, chalk, sulphur, etc.; then metals such as lead, copper, tin and iron may be studied; the increase in the weight of these latter is in striking contrast to the inalterability of substances like sand and salt and the destruction of vegetable and animal substances. Chalk, from which lime is made by burning, is found to occupy a middle position, losing somewhat in weight when strongly heated. The exceptional behaviour of coal among mineral substances and of salt among food materials, is shown to be capable of explanation inasmuch as coal is in reality a vegetable and salt a mineral substance; but sulphur remains an instance of exceptional behaviour requiring explanation. It is not exceptional in being combustible—as metals like magnesium and zinc are combustible—but in affording no visible product. The smell of burning sulphur, however, serves to suggest that perhaps after all there is a something formed which is an invisible substance possessed of an odour and then follows quite naturally the suggestion that perhaps in other cases where no visible or perceptible product is obtained—as on burning charcoal, for instance—there may nevertheless be a product. Whereas, therefore, in Stage I the pupil will have learnt to appreciate the existence of a great variety of substances and will have gained the power of describing their outward appearance more or less fully; and in Stage II, having learnt how to measure and weigh, will acquire the habits of determining by measurement certain properties of substances and will thus be in a position to express in exact terms the kind of differences observed; in Stage III the pupil will be led to see that profound changes

take place on burning substances and that these changes involve something more than the destruction of the things burnt. The foundation is thus laid for the study of change, *i.e.* chemical studies proper.

STAGE IV.—*The Problem Stage*

Many of the changes observed in the course of the experiments made in Stage III might be examined and their nature determined but the best to take first is a very familiar case, that of the rusting of iron.

PROBLEM I. *To determine what happens when iron rusts.*—The pupil *must* be led in the first instance to realise that a problem is to be solved and that the detective's method must be adopted and a *clue* sought for. It is a familiar observation that iron rusts, especially when wet; what happens to the iron, why does it rust, is the iron alone concerned in the change? No information can be gained by looking at it—perhaps the balance which has brought to light so much in Stage III may be of service, so the iron is allowed to rust in such a manner that any change in weight can be observed. A few grams of iron filings or borings are put on to a weighed saucer or clock glass along with a bit of stiff brass or copper wire to be used as a stirrer; the iron is weighed, then moistened and exposed under a paper cover to keep off dust, preferably in a warm place; it is kept moist and occasionally stirred. After a few days it is dried in the oven and then weighed. The weight is greater. *Something from somewhere has been added to the iron.* Thus the clue is gained. Where did this something come from? The fact that when a tumbler, for instance, is plunged mouth downwards into water the

water does not enter and that on gradually tilting the tumbler to one side something escapes—viz. air—at once affords a demonstration of the presence of air in the space around us. The iron rusted in this air but was kept moist, so it may have taken up the something from either the air or the water. To ascertain whether the air takes part in the rusting, some iron borings are tied up in a bit of muslin and the bag is hung from a wire stand placed in a (jam) pot full of water and a so-called empty (pickle) bottle, which in reality is full of air, is inverted over the iron; in the course of a few hours, as the iron rusts, the water is observed to rise until it occupies about one-fifth of the jar (determined by measuring or weighing the water); the something added to the iron during rusting appears therefore to come from the air. The all-important fact is thus discovered that the rusting is a change in which not the iron alone but also the air is concerned. The experiment is several times repeated, fresh iron being used with the same air and the same iron put in succession into fresh portions of air—the same result is always obtained: whence it follows that whatever it is in the air which takes part in the rusting, the air as a whole is not active. The changes previously observed to take place when iron, copper, lead, zinc, etc., were heated in air, are then recalled; as the metals were found to increase in weight, it would appear probable that in these cases of change also the air was concerned.

These results at once suggest the question, What is air? So much having been learnt by studying the change which iron undergoes in rusting, other changes which happen in air therefore are next studied.

PROBLEM II. *To determine the nature of the changes*

which take place on burning substances in air.—The use of phosphorus is introduced by reference to a match. Phosphorus is then burnt under a bell jar over water and the result noted: the disappearance of some of the air again shows that the air is concerned. The fact that phosphorus smokes when taken out of the water in which it is always kept suggests that some change is going on, so a stick of phosphorus is exposed in air as in the previous experiment with iron: soon one-fifth has disappeared and the phosphorus then ceases to smoke. The *quantitative* similarity of the two results suggests that iron and phosphorus behave alike towards air and *vice versa;* it also serves to confirm the idea that some constituent of the air, present only to the extent of about one-fifth, is active. But nothing is to be taken for granted, so iron is exposed in the phosphorus-air residue and phosphorus in the iron-air residue: as no change occurs there is no room left for doubt. Recalling the experiments in which various metals were burnt in air in order to determine whether in these cases the same constituent of the air was concerned in the change, air from which the active constituent has been removed by means of iron is passed through a heated tube containing bits of the metals: no change is observed, so it is evident that as a rule, if not always, one and the same constituent of air is concerned. The experiments with iron and phosphorus, although they show that the air is concerned in the changes which are observed to take place, do not afford any information whether or no the water which is also present is concerned in the change. Phosphorus is therefore burnt in a dry pear-shaped flask closed with a rubber stopper: on removing the stopper under water some water enters;

by measuring this and the amount of water which will fill the flask the same result is obtained as in the previous cases. To be certain whether in this case anything enters or escapes from the flask it is weighed before and after the phosphorus is burnt. There is no change in weight. But does nothing escape? Yes, much heat: whence it follows that heat is not material—that, although some of the air disappears, it is merely because it has become affixed to or absorbed by something else. This has been proved in the case of the rusting iron and the burnt metals. To obtain indisputable evidence in the case of the phosphorus this is burnt in a current of air in a tube loosely filled with asbestos to retain the smoke: the weight is found to increase. The observation that the phosphorus ceases to burn after a time suggests the introduction of a burning taper into the residue left by iron, etc.; it is found to be extinguished. Then a candle and subsequently a gas flame may be burnt in a bell jar full of air over water. Reversed combustion may then be demonstrated in order to fully illustrate the reciprocal character of the phenomena. Thus it is ascertained that although all ordinary cases of combustion are changes in which the air is concerned, not the air as a whole but a particular constituent is active; and it is beyond doubt that the same constituent is always active but active under different conditions; it is realised also that the production of heat is the consequence of the union of the substance burnt with the active substance in air. The experiment of exposing phosphorus in air affords the opportunity of demonstrating the evolution of heat even in a case where no visible combustion occurs, as the phosphorus is always observed to melt. At this stage careful note should be taken of the

appearance of the different products of combustion and of a change such as that which occurs when the product from phosphorus is exposed to the air.

PROBLEM III. *To separate the active from the inactive constituent of air.*—It now has become of importance to get this active constituent of the air by itself and the question arises whether it cannot be separated from one of the metals or other substances with which it has been found to combine. The pupil is therefore told to collect information about the different substances formed by burning metals, etc.—whether they can be obtained in sufficient quantity to work with, etc. Iron rust and iron scale are easily obtainable and so is copper scale; zinc is burnt to produce zinc white, which is used as paint; lead is also burnt on a large scale and in this case it appears that one or other of two substances is formed—litharge at a high temperature, red lead at a lower temperature. This peculiarity of lead suggests the study of the two products in the hope of discovering the clue to a method. Weighed quantities of the litharge and red lead are heated; it is observed that only the latter changes in appearance and that it loses weight. But what does it lose? It was formed by merely roasting lead in the air and the something which it loses must therefore have been derived from the air. When the red lead is heated in a tube a gas is given off which may be collected and tested—how? with a taper or glowing splinter as it is to be supposed that the gas will support combustion if, as is to be expected, it is the active constituent of air. The *discovery* of the active constituent of air is thus made! If air consist of this gas and that which remains after exposing phosphorus or iron in air, then by adding to such residual air as

much of the gas from red lead as was withdrawn, air should be re-obtained; this is found to be the case. The names of the two gases are now stated *for the first time* and an easy method of preparing oxygen is demonstrated—such as that of heating a chlorate—but without any explanation. The conclusion previously arrived at, that probably in all the cases previously studied of changes occurring in air the oxygen is the active substance, may now be verified by burning or heating in oxygen the substances which had been burnt in air. The comparison of the densities of the two gases with that of air should then be made.

So much having been learnt of the chemistry of air, the study of the pressure exercised by air may next be taken up and the common pump, the force pump, the barometer and air currents may be discussed and explained. Nowadays the charts given in the daily papers and the Ben Nevis and Glycerin barometer readings quoted in the *Times* make it particularly easy to explain the barometer. The pupils should be led to make barometer curves.

PROBLEM IV. *To determine what happens when chalk is burnt to lime.*—The discovery of the *composition* of the air in the course of experiments made with the object of determining the nature of certain changes naturally suggests that the attempt should be made to ascertain the composition of other things by studying the changes which they undergo. Chalk is known to give lime when burnt and experiments made in Stage III have indicated that chalk loses something when burnt—the idea that an invisible something is given off is especially probable after the experiments with red lead have been made: so it is decided to heat chalk strongly; but before doing this chalk and lime

are examined comparatively. Chalk is observed not to be altered by water; on shaking it with distilled water and evaporating some of the filtered liquid in a weighed dish, very little residue is obtained—so it is established that it is but very slightly soluble in water. Lime is slaked, weighed quantities of lime and water being used; the retention of a considerable amount of water, even after exposing the slaked lime in the drying oven, shows that the slaking involves a definite change in composition—that slaked lime is lime and water. The solubility of the lime is next determined and found to be considerably greater than that of the chalk. It is found that chalk is but very slightly altered in weight when heated over a gas flame and that it is only when it is strongly heated that it is converted into lime: so the chalk is strongly heated in an iron tube in a Fletcher blow-pipe furnace: gas is more or less freely given off; subsequently it is found that the chalk has become lime. The gas is tested with a taper, which it extinguishes, so it cannot be oxygen but may be nitrogen; its density is therefore compared with that of nitrogen and found to be greater, so evidently it is a peculiar gas and may be called chalk gas. If chalk consist of this gas and lime, it should be possible to reproduce chalk from them; so the gas is passed through a small weighed tube containing lime—the tube is found to get heavier. But lime and chalk are so much alike that it is difficult to say that chalk is formed: perhaps dissolved lime will act similarly; the gas is therefore passed into or shaken up with lime-water. The precipitate which forms looks like chalk and probably is but this remains to be decided. The discovery of this behaviour of chalk gas is important as affording a

means of again comparing the gas from chalk with nitrogen. In working with lime-water it is scarcely possible to avoid noticing that a film forms on its surface; by exposing a quantity of the lime-water a considerable amount of the precipitate is obtained: its resemblance to chalk having been established and the possible presence of chalk gas in air is suggested; this and the precipitates previously obtained are collected, dried and then introduced into pieces of narrow hard glass tubing, connected to wash-bottles containing lime-water and on heating strongly by means of a blow-pipe flame, while air is sucked through to carry forward any gas into the lime-water, the white precipitates are again obtained, so no doubt remains that the original precipitates were chalk. Incidentally the discovery is thus made that air contains something besides oxygen and nitrogen, viz., chalk gas.

It being thus established that chalk consists of two things, lime and chalk gas, at this stage it is pointed out how firmly these two constituents hold to each other in the chalk. The absorption of the gas by the lime—its entire disappearance in fact—is commented on. Accurate determinations of the loss of weight on heating crystallised chalk (calc spar) should at this stage be carried out before the class, if not by the pupils, so that the numbers may be quoted and that it may become impressed on them that the proportions in which the lime and chalk gas are present is constant. Their attention may be recalled to the oxides previously studied, it being pointed out that on inspection these afford no indication that they contain oxygen: that here again the gas entirely loses its individuality on entering into union or combination. That oxides contain their constituents in fixed propor-

tions may be demonstrated experimentally by oxidising finely-divided copper and determining the increase in weight, lime being used as drying agent. In this way the characteristics of *compounds* are elucidated. Then the comparison may be made with air and the fact made clear that it behaves as a mere mixture. Still no reference should be made to elements.

PROBLEM V. *To determine what happens when organic substances are burnt.*—The experiments thus far made have shown that phosphorus and a number of metals burn in the air because they combine with the oxygen, forming oxides, heat being given out *as a consequence;* but that chalk when burnt is split up or decomposed into lime and chalk gas, this result being a consequence of the heating alone, the air having nothing to do with it. It remains to ascertain what happens when organic substances are burnt as these give no visible product beyond a little ashes. As in all cases when vegetable or animal substances are burnt a certain amount of "char" is obtained, which then gradually burns away, charcoal or coke is first studied. It having been discovered that the oxygen in air is the active cause of burning in many cases, it appears probable that the air is concerned in the burning of charcoal, coal, etc. As when once set fire to these continue to burn, the charcoal is at once heated in oxygen: it burns, but no visible product is formed; it therefore follows that if the charcoal is oxidised the oxide must be an invisible gas. How is this to be tested for? What gases are already known to the pupil? How are these distinguished? Oxygen is excluded. Is it perhaps nitrogen and is not perhaps the nitrogen in air merely used-up oxygen, as it were, produced by the burning of

organic substances? Or is it perhaps that gas which was found in the air along with oxygen and nitrogen, which turned lime-water turbid? This last being an easy test to apply is at once tried; as the lime-water is rendered turbid, to leave no doubt a sufficient amount of the gas is prepared and passed into lime-water and the precipitate is collected: it is found to give off chalk gas when heated and when the loss it suffers on heating is determined it is found to be the same as that suffered by the precipitate prepared from chalk gas. Thus the discovery is made that chalk gas is an oxide of carbon and that chalk consists of at least three things.

It may be objected that to make the experiment in this manner takes too much time; but to this it may be answered that such experiments are precisely similar to those made in actual practice and that they exercise a most important influence in teaching the pupils to take nothing for granted, never to jump at conclusions and to rest satisfied if they progress surely, however slow the advance may be.

The char from a number of organic substances may now be burnt in oxygen and the gas passed into lime-water; chalk gas is found in every case to be a product and hence the presence of a common constituent—carbon—in all is established. In burning substances such as sugar, it is scarcely possible to avoid noticing the formation of a liquid product, so it is evident that chalk gas is not the only product of their combustion or carbon their only constituent.

Food materials generally having been found to contain "carbon," as they are obviously in some way destroyed within the body and it is known that air is necessary for life, the question arises, What becomes

of food and why is air necessary for life? Is the food, perhaps, in large part "burnt up" within the body, thus accounting for the fact that our bodies are always warm? The characteristic product of combustion of carbonaceous substances is therefore tested for by breathing into lime-water. The discovery thus made affords an opportunity for a digression and for explaining how plants derive their carbon from the air.

PROBLEM VI. *To determine what happens when sulphur is burnt.*— From the results of the experiments with carbon, it appears probable that the disappearance of sulphur when burnt is also really due to its conversion into a gaseous oxide, so it is kindled and introduced into oxygen: if it be burnt over water in a bell jar in a spoon passing through the stopper (a rubber cork), the water is seen to rise; if, on the other hand, it be burnt in a dry flask closed by a rubber cork carrying a gauge-tube, as suggested by Hofmann,[1] the volume is seen to be almost unchanged after combustion. It follows, therefore, that the sulphur and oxygen unite and form a soluble product. Sulphur is next burnt in a tube in a current of oxygen and the gas is passed into water; a solution is thus obtained having the odour of the gas and sour (acid) to the taste. The fact that carbon and sulphur —both non-metals—behave alike in yielding gaseous oxides suggests that a comparison be made of their oxides: so the acid solution is added to lime-water; a precipitate is formed which redissolves on adding

[1] By burning carbon also in this way a most effective demonstration is given of the fact that no loss or gain of matter attends the change and that only heat escapes; the results in the case of carbon and sulphur are particularly striking, as the products are gaseous and invisible.

more of the sulphur gas solution; on the other hand, on adding the lime-water to the acid liquid, this latter after a time loses its characteristic smell. There can be no doubt, therefore, that the sulphur gas does in some way act upon the lime. The discovery that the addition of more of the sulphur oxide leads to the dissolution of the precipitate which it first forms in lime-water suggests trying the effect of excess of the oxide of carbon on the lime-water precipitate; this is done and the discovery is made that the precipitate gradually dissolves. The solubility of the new substance may then be determined by passing the gas into water containing chalk in suspension, filtering and evaporating. This leads to the observation that on heating the liquid a precipitate is formed, which is soon found to be chalk. An opportunity is thus afforded of explaining the presence of so much "chalk" in water; of demonstrating its removal by boiling and by means of lime-water; and the effect it has on soap.

The observation that the oxides of both carbon and sulphur combine with lime suggests trying whether the one will turn out the other, so the solution of the sulphur oxide is poured on to chalk: effervescence is observed and on passing the gas into lime-water a precipitate is obtained. The production of this effect by the *acid* solution suggests trying common vinegar—a well-known *acid* substance. This also is found to liberate chalk gas and the discovery of an easy method of preparing chalk gas is thus made. The oxide formed on burning phosphorus, having previously been found to give an acid solution, is tried and it is found that it also liberates chalk gas. As a good deal of vinegar is found to give very little chalk gas, the question arises, Are there not acids to

be bought which will have the same effect and are stronger and cheaper? On inquiry it is found that sulphuric acid or oil of vitriol, muriatic acid or spirits of salts and nitric acid or aquafortis may be bought and that these all act on chalk. The behaviour of chalk with acids affords a means of testing the lime-water precipitate obtained in working out Problems IV and V. In this manner the pupil is led to realise that certain agents may very readily produce effects which are only with difficulty produced by heating—that the *chemical agent* may produce very powerful effects. The ready expulsion of the oxide of carbon from the chalk suggests that other substances not yet studied, such as the metals, when treated with acids may behave in a special manner which will afford information as to their nature. At this point, prior to making the experiments with the acids, an explanation may be given of the names *oil of vitriol, spirits of salts* and *aquafortis;* the processes by which they are made may be described and illustrated, without, however, any attempt being made to explain them from the chemical point of view. The sulphuric acid should be made from green vitriol and its behaviour on dilution should be demonstrated as well as its use as a drying agent.

PROBLEM VII. *To determine what happens when metals are dissolved in acids.*—Iron, zinc, lead, tin, copper and silver may be taken. On pouring diluted oil of vitriol on to iron or zinc, the metal dissolves with effervescence; the gas is collected and when tested is found to burn. Thus a new gas is discovered, differing from all which have previously been studied, inasmuch as it is combustible; in order not to interrupt the study of the action of acids on metals,

however, its further examination is postponed for a while. Resuming the experiments with metals, lead, tin, copper and silver are found not to be acted upon by diluted oil of vitriol.

Muriatic acid, in like manner, dissolves iron and zinc and also tin with effervescence; the gas which is given off in each case exhibits the same behaviour as that obtained from iron or zinc and diluted oil of vitriol. Lead, copper and silver are not appreciably affected.

Aquafortis is found to dissolve not only iron and zinc but also copper, lead and silver and to convert tin into a white substance—to attack all the metals, in fact, thus justifying its name. The gas which is given off as the metal dissolves is observed to be coloured; when it is collected over water, however, it is seen to be colourless but to become coloured on coming into contact with air—oxygen and nitrogen are, therefore, added to portions of the gas over water. In this manner, not only is a new gas discovered but also a test for oxygen; and opportunity is afforded of here calling attention to the fact that air behaves exactly as oxygen, that the oxygen in air appears to be unaffected by its association with nitrogen—that, in fact, it is uncombined. From these experiments it is obvious that metals and acids interact in a variety of ways. Finally, the dissolution of gold and platinum by aqua regia may be demonstrated.

PROBLEM VIII. *To determine what happens when oxides are acted on by acids.*—In the course of the previous experiments a number of oxides have been prepared by burning various metals in air; these are found to be unchanged by water. The discovery that acids act on metals suggests a trial of the effect which

acids will have on their oxides; so the oxides of zinc, iron, copper and lead are submitted to the action of the three acids previously used. Sulphuric acid is found to dissolve zinc oxide, iron rust and copper oxide but no combustible gas is evolved; excess of the oxide may be used and the filtered liquid concentrated; the crystals which separate may be examined and compared with those obtained by dissolving the metal in sulphuric acid, etc. Litharge apparently is not changed by sulphuric acid but red lead is, although not dissolved. Muriatic acid being used, all the oxides are found to dissolve and in the case of red lead a greenish yellow gas is given off possessing a most disagreeable smell; this is noted as a case for study. The product from the lead oxides is observed to crystallise out from the hot liquid on standing, so the undissolved original product is boiled up with water and the solution is filtered, etc. Attention is thus directed to the difference in solubility of the products. Next, aquafortis is used; again all are dissolved, except the red lead, which, however, is obviously altered. In the case of the lead oxides the product is again less soluble than those afforded by the other oxides but more soluble than the product obtained on using muriatic acid. The pupil has already been led to realise that of two substances capable of acting on a third, such as chalk gas and sulphur gas, which both combine with lime, one may be the stronger and may turn out the other, sulphur gas turning out chalk gas from chalk. A comparison of the three acids with the object of ascertaining which is the strongest is therefore suggested—the metal or oxide is dissolved in one of the acids and the others are then added. No positive result is obtained in the case of zinc, iron or copper; but the solution

of lead in nitric acid is precipitated by muriatic and by sulphuric acid; the precipitate caused by the former is found to dissolve in boiling water and to crystallise out in exactly the same way as the substance obtained from lead oxide and muriatic acid. The sulphuric acid product is found to be almost insoluble in water and also in muriatic and nitric acids; these observations make it possible, by examining the behaviour towards muriatic and nitric acids of the products of the action of sulphuric acid on the lead oxides, to establish the fact that the product is the same whether lead be dissolved in nitric acid and sulphuric acid be then added or whether either of the oxides be treated with sulphuric acid. It is further evident that those acids which give difficulty soluble or insoluble products act with difficulty if at all on the metal. Other metals besides those mentioned may be now studied and, a solvent being found, the acids which do not dissolve the metal may be added to the solution. In this way, for example, the chloride test for silver is discovered.

In experimenting with acids the pupils can hardly fail to stain their clothes and their fingers. The observation that acids alter colours serves to suggest experiments on the action of acids on colours, especially those of leaves and flowers. The use of litmus, methyl-orange, cochineal, etc., may then be explained. As various oxides have been found to "neutralise" acids, the study of their effect on the colours altered by acids is suggested. Lastly, a few experiments with vegetable and animal substances, sugar, etc., may be made, to demonstrate the corrosive action of oil of vitriol and aquafortis.

PROBLEM IX. *To determine what happens when the gas obtained by dissolving iron or zinc in sulphuric*

or muriatic acid is burnt.—The gas has been observed to burn with a smokeless, odourless flame. To ascertain whether, as in all other cases of combustion previously studied, the oxygen of the air is concerned in the combustion, a burning jet of the gas is plunged into a dry cylinder full of oxygen, in which it is not only seen to continue burning but it is also noticed that drops of liquid condense on the cylinder above the flame; this immediately suggests that the product is a liquid. The jet is found to be extinguished in nitrogen, so evidently when the gas burns it forms an oxide. The experiment is repeated and the gas burnt in a bell jar full of oxygen over water: the water rises as the combustion proceeds, proving that the oxygen is used up. To collect a sufficient quantity of the product for examination, the dried [1] gas is burnt at a jet underneath a Florence flask through which a stream of cold water is allowed to circulate: the neck of the flask is passed through the neck of a bell jar and the flask and bell jar are clamped up in an inclined position, so that the liquid which condenses may drop into a small beaker placed below the rim of the jar. What is the liquid? It looks very like water and is without taste or smell. Is it water? How is this to be ascertained? What are the properties of water? The knowledge previously gained here becomes of importance. It has been observed that frozen water melts at 0° Centigrade, that water boils at 100° and that one cubic centimetre weighs one gramme at 4° C.; so the liquid is frozen by the ice-maker's mixture of ice and salt, a thermometer being plunged into it so

[1] The importance of drying the gas is realised without difficulty, as previous observations have shown that the air is moist and as the gas is given off in presence of water; lime may be used.

that the solid ice forms on the bulb: the melting-point is then observed. Subsequently, the boiling-point is determined, a little cotton-wool being first wrapped around the bulb of the thermometer. Lastly, the density of the liquid may be determined. It is thus established that the gas yields water when burnt: the name of the gas may now *for the first time* be mentioned and explained. The results thus obtained leave little doubt that water is an oxide of hydrogen; but in order to place this beyond doubt it is necessary to exclude nitrogen altogether. How is this to be done? Red lead is known to consist of lead and oxygen only; it readily parts with at least a portion of its oxygen; so dried hydrogen is passed over red lead, which is then gently heated. Again a liquid is obtained which behaves as water, so there can be no doubt that water is an oxide of hydrogen. Water is not obtained on merely mixing oxygen and hydrogen; it is only produced when combustion takes place. To start the combustion a flame is applied to a small quantity of a mixture of the two gases: a violent explosion takes place. An opportunity is here again afforded of calling attention to the entire change in properties which takes place when the compound is formed. On heating red lead in hydrogen, lead is obtained, although on heating it alone the oxide loses only a portion of its oxygen; and the "reduction" takes place very readily; evidently, therefore, hydrogen is a powerful agent. This observation suggests further experiments. Will it not be possible to remove oxygen by means of hydrogen from other oxides which are not altered on heating? and will not other combustible substances besides hydrogen remove oxygen from oxides?

PROBLEM X. *To determine what happens when*

hydrogen and other combustible substances are heated with oxides.—Zinc oxide, iron rust and copper oxide are now heated in a current of hydrogen: the first remains unaltered, the other two are seen to change, a liquid being formed which it cannot be doubted is water; the copper oxide evidently becomes reduced to copper. Is the iron rust similarly reduced to the metallic state? How is iron to be tested for? Iron is attracted by the magnet and when it dissolves in diluted oil of vitriol hydrogen is evolved. Applying these tests, no doubt remains that the iron rust is deprived of its oxygen.

Litharge and copper oxide may then be mixed with soot or finely powdered charcoal and heated in tubes; gas is given off which renders lime-water turbid and metallic lead or copper is obviously obtained. It is thus established that some but not all oxides may be deprived of their oxygen by means either of hydrogen or carbon. Opportunity is here afforded of explaining the manufacture of iron.

Several dried combustible organic substances—sugar, bread and meat—may now be burnt with copper oxide in a tube the fore part of which is clean and which is kept cool: liquid is seen to condense while "chalk gas" is given off; the liquid has the appearance of water and sufficient may easily be obtained to ascertain whether it is water. The presence of hydrogen in organic substances is thus discovered; its origin from water may now be explained and the double function of water in the plant and animal economy may be referred to—viz. that it both enters into the composition of the animal and plant structure and also acts as a solvent. The combustion of ordinary coal gas, of alcohol, of petroleum, of oil and of candles, may then

be studied and the presence of hydrogen in all of these noted.

PROBLEM XI. *To determine whether oxides such as water and chalk gas may be deprived of oxygen by means of metals.*—It being found that hydrogen and carbon withdraw the oxygen from some but not from all metallic oxides, it follows that some metals have a stronger, others a weaker, hold upon or "affinity" to oxygen than has either hydrogen or carbon; the question arises whether any and which metals have so much greater an affinity to oxygen that they will withdraw it from hydrogen and carbon. Copper and iron have been found to part with oxygen but zinc and magnesium did not, so these four metals may be studied comparatively. Steam is passed through a red-hot copper tube full of copper tacks: no change is observed. The experiment is repeated with an iron tube charged with bright iron nails: a gas is obtained which is soon recognised to be hydrogen and on emptying out the nails they are found to be coated with black scale. Zinc and then magnesium are tried: like iron, they are found to liberate hydrogen. Chalk gas is next passed over red-hot copper and is found to remain unchanged but on passing it over red-hot iron or zinc a gas is obtained which burns with a clear blue smokeless flame: this gas is not absorbed by milk of lime but on combustion yields chalk gas, so it evidently contains carbon and is a new combustible gas. Like hydrogen, it is found to afford an explosive mixture with oxygen. Finally, magnesium is heated in chalk gas: it is observed to burn and the magnesium to become converted into a blackish substance unlike the white oxide formed on burning it in air. But it is to be expected that this oxide is produced—to remove

it, as it is known from previous experiments to be soluble in muriatic acid, this acid is added: a black residue is obtained. What is this? Is it not probable that it is carbon? If so, it will burn in oxygen yielding chalk gas. So the experiment is made. These experiments in which hydrogen is obtained from water and carbon from chalk gas afford the most complete "analytic" proof of the correctness of the conclusions previously arrived at regarding water and chalk gas, which were based on "synthetic" evidence; taken together, they illustrate very clearly the two methods by which chemists determine composition.

As hydrogen and carbon form oxides from which oxygen may be removed by means of some metals but not by all, the question arises, which has the greater hold upon or affinity to oxygen—carbon or hydrogen? As it is the easiest experiment to perform, steam is passed over red-hot charcoal: a combustible gas is obtained which yields water and chalk gas when burnt, so evidently the hydrogen is deprived of its oxygen and this latter combines with the carbon, forming the combustible oxide of carbon. Will not carbon partly deprive chalk gas of its oxygen? The experiment is made and it is found that it will. These results afford an opportunity of calling attention to and explaining the changes which go on in ordinary fires and in a furnace.

PROBLEM XII. *To determine the composition of salt gas and the manner in which it acts on metals and oxides.*—It has previously been demonstrated that spirits of salt or muriatic acid is prepared by acting on salt with oil of vitriol and passing the gas which is given off into water; the solution has been found capable of dissolving various metals and oxides, chalk, lime, etc.: as water alone does not dissolve these

substances the effect is apparently attributable to the dissolved gas, so it becomes of interest to learn more of this gas in order that its action may be understood. It is first prepared; its extreme solubility in water is observed and also the fact that as it dissolves much heat is given out; and it is noted that although colourless and transparent it fumes in the air. How is its composition to be determined? Is there any clue which can be followed up? Reference is made to the previous observations and it is noted that its solution dissolves various metals with evolution of hydrogen; water alone has no such effect. Is this hydrogen derived from the water or from the dissolved gas? The gas alone is passed over heated iron turnings and the escaping gas is collected over water: it proves to be hydrogen, so evidently salt gas is a compound of hydrogen with something else. How is this something else to be separated from the hydrogen? Do not previous experiments suggest a method? Yes, they have proved that hydrogen has a marked affinity to oxygen and now it is recollected that on treating muriatic acid with red lead—a substance rich in oxygen—a greenish-yellow gas is obtained. The experiment is repeated on a larger scale and the gas is examined. If it is contained together with hydrogen in salt gas, perhaps salt gas will be obtained on applying a flame to a mixture of the two gases just as water is from a mixture of oxygen and hydrogen: the mixture is made and fired and the result leaves little doubt that salt gas does consist of hydrogen in combination with the greenish-yellow gas —chlorine. Whence is this chlorine derived—from the salt or the sulphuric acid?

The notes are again consulted and it is seen that

a solution of silver in nitric acid gave a characteristic precipitate with muriatic acid but not with sulphuric, so salt solution is added to the silver solution and a precisely similar precipitate is obtained, leaving little doubt that the chlorine is derived from the salt. It is now easily realised that the iron and zinc displace the hydrogen of the dissolved hydrogen chloride. What happens when the oxides are acted on? In addition to the metal they contain oxygen, which is known to combine readily with hydrogen, forming water; is water formed? Zinc oxide is therefore heated in hydrogen chloride; a liquid is obtained which behaves exactly as a solution of hydrogen chloride in water. When the action is complete and all that is volatile has been driven off by heat, a solid remains very like fused common salt—doubtless zinc chloride, since it is to be supposed that as the hydrogen has taken the place of the zinc the chlorine has taken the place of the oxygen. What, then, is the action of hydrogen chloride on chalk? It evidently not only separates the chalk gas from the lime but also dissolves this latter. What is formed? Dry (unslaked) lime is therefore heated in a current of hydrogen chloride. It behaves just as zinc oxide, yielding a liquid product—evidently a solution of hydrogen chloride in water, as it dissolves zinc with evolution of hydrogen and the residue is like that of zinc chloride. The important discovery is thus made that lime also is an oxide—that chalk, in fact, is a compound of two oxides; the resemblance of lime to zinc oxide and magnesium oxide is so striking that the conclusion is almost self-evident that lime is probably a metallic oxide and it may be here pointed out that this actually is the case. The gradual dis-

covery of the composition of chalk in the manner indicated is an especially valuable illustration of chemical method and serves to show how chemists are often obliged to pause in their discoveries and to await the discovery of new facts and methods of attack before they are able to completely solve many of the problems which are submitted to them. The solids obtained on dissolving zinc oxide and lime in muriatic acid and boiling down the solution, when all the water is driven off, are white solids like fused salt. But on exposure they gradually become liquid. In so doing they increase in weight and evidently behave like sulphuric acid. Probably water is absorbed from the air: no change takes place when they are kept over sulphuric acid or dry lime. In this way two new desiccating agents are incidentally discovered.

PROBLEM XIII. *To determine the composition of washing soda.*—The study of this substance is of importance as introducing the conception of an alkali. The preparation of washing soda from salt is first described. On heating the crystals they melt and give off "steam"; the experiment is made in such a way that a quantity of the liquid is obtained sufficient to place beyond doubt that it is water. The water is found to be easily driven off on heating the crystals in the oven and to constitute a very large proportion of the weight of the crystals. The conception of water of crystallisation is thus gained. On heating the dried substance to full redness in the platinum dish, no loss occurs. The residue dissolves in water and "soda crystals" may again be obtained from the solution, so that heat does not affect it. Perhaps acids which have been found to act so powerfully in other cases will afford some clue—on trial this is found to

be the case: a colourless, odourless gas is given off, which extinguishes a burning taper. Is this perhaps nitrogen or is it chalk gas? The lime-water test at once decides that it is the latter. So it is determined that washing soda, like chalk, is a compound of chalk gas—but with what? With an oxide? The dried substance is heated in hydrogen chloride: chalk gas is given off as before and a liquid which is soon recognised as water saturated with hydrogen chloride. The residue dissolves in water and separates from the concentrated solution in crystals exactly like salt: in fact, it is soon recognised to be salt; evidently, therefore, that which is present in salt along with chlorine is present in soda crystals along with oxygen, chalk gas and water. The preparation of the metal sodium from soda is then explained. Acquaintance being thus made with compounds of chalk gas with two different oxides, the question arises, which oxide has the greater affinity to the chalk gas? Will lime displace sodium oxide from soda or *vice versa?* On adding lime-water to soda solution, a precipitate of chalk is formed. What does the solution contain? Lime-water contains lime in combination with water; is the sodium oxide present in combination with water? Soda is boiled with milk of lime (in an iron saucepan to avoid breakage) until it no longer affects lime-water; afterwards the liquid is poured off and boiled down. The product is very unlike soda: it is very caustic and when exposed to the air becomes liquid. If it is a substance analogous to slaked lime, it should combine with chalk gas and be reconverted into soda; this is found to be the case. Caustic soda is thus discovered. Chalk and lime are known to neutralise acids; both soda and caustic soda are found to do so

and their effect on vegetable colours is found to be the reverse of that of acids. At this stage the origin of the name alkali is explained and it is pointed out that the oxides which have been studied may be arranged in two groups of alkali-like or *alkylic* and acid-forming or *acidic* oxides, the former being derived from metals, the latter from non-metals. The production of *salts* by the union of an oxide of the one class with the oxide of the other class is then illustrated by reference to earlier experiments.

The point is now reached at which the results thus far obtained may be reconsidered. The student has been led in many cases to make discoveries precisely in the manner in which they were originally made; and it is desirable that at this stage, if not earlier, the history of the discovery of the composition of air and water, etc., should be briefly recited. It is then pointed out that a variety of substances have been analysed and resolved into simpler substances—air into oxygen and nitrogen, water into oxygen and hydrogen, etc.; that these simpler substances thus far have resisted all attempts to simplify them further and are hence regarded as *elements*. A list of the known elements having been given, the diverse properties of the elements may be illustrated from the knowledge gained in the course of the experiments. The fact that when elements combine compounds altogether different in properties from the constituents are formed also meets with manifold illustration. Too little has been ascertained to admit of any general conclusion being arrived at with regard to the proportions in which elements combine but it is clear that they may combine in more than one proportion, since two oxides of carbon have been discovered and in the only cases studied—

viz. copper oxide and chalk—the composition has been found not to vary. The existence of various types of compounds has been recognised and a good deal has been learnt with reference to the nature of chemical change. But, above all, the method of arriving at a knowledge of facts has been illustrated time after time in such a manner as to influence in a most important degree the habit of mind of the careful student. New facts have been discovered by the logical application of previously discovered facts: the habitual and logical use of facts has been inculcated. This is all-important. It has become so customary to teach the facts without teaching how they have been discovered that the great majority of chemical students never truly learn the use of facts; they consequently pursue their daily avocations in a perfunctory manner and only in exceptional cases manifest those qualities which are required of the investigator; their enthusiasm is not awakened and they have little desire or inclination to add to the stock of facts. It must not for one moment be supposed that the object of teaching chemistry in schools is to make chemists. Habits of regulated inquisitiveness, such as must gradually be acquired by all who intelligently follow a course such as has been sketched out, are, however, of value in every walk of life; and certainly the desire to understand all that comes under observation should as far as possible be implanted in every one.

STAGE V.—*The Quantitative Stage*

The *quantitative* composition of many of the substances which have previously been studied qualitatively should now be determined—in some cases by the

teacher in face of the pupils, so that every detail may be observed and all the results recorded; in other cases by the pupils.

The composition of water is first determined by Dumas' method; this may easily be done and fairly accurate results may be obtained in the course of a couple of hours. The results obtained by Dumas and subsequent workers should then all be cited and attention having been drawn to the extent to which such experiments are necessarily subject to error, the evidence which the results afford that hydrogen and oxygen combine in certain *fixed and invariable proportions* to form water is especially insisted upon.

The composition of chalk gas is next determined; this also is easily done, as impure carbon[1] (lampblack) may be burnt and the hydrogen allowed for. Again, attention is directed to the results obtained by skilled workers and the evidence which they afford that chalk gas never varies in composition.

The composition of copper oxide has already been ascertained; it may be redetermined by reducing the oxide in hydrogen: in fact, in determining the composition of water.

The lead oxides may be reduced in a similar manner, the oxide obtained by igniting white lead as well as red lead and the brown oxide obtained by acting on red lead with nitric acid being used. In this way it is ascertained that the brown oxide is the highest oxide; the loss in weight which this oxide suffers when ignited may then be determined.

Tabulating the results thus obtained, after calculating with what amount of the particular element that quantity of oxygen is associated which in water is

[1] Electric light carbon is a better material.

combined with one part by weight (*unit weight*) of hydrogen, numbers such as the following are obtained:—

1 part of	hydrogen	is combined with	8 parts of	oxygen	in	water	
3 ,,	carbon	,,	,,	8	,,	,,	chalk gas
31·5 ,,	copper	,,	,,	8	,,	,,	copper oxide
103·5 ,,	lead	,,	,,	8	,,	,,	lead oxide (litharge)
51·8 ,,	,,	,,	,,	8	,,	,,	,, (brown).

These clearly illustrate the fact that elements combine in very different proportions and the results obtained with the lead oxides afford also an illustration of combination in multiple proportion.

The amounts of silver and lead nitrates formed on dissolving silver and lead in nitric acid are next determined by evaporating the solutions of known weights of the metals in porcelain crucibles on the water-bath and then drying until the weight is constant; accurate results may easily be obtained and these two exercises afford most valuable training. The nitrates are subsequently evaporated with muriatic acid and the weights of the products determined. What are these products? Does the metal simply take the place of the hydrogen in hydrogen chloride as zinc does when it dissolves in muriatic acid? If so, the products are silver and lead chlorides and it may be expected that the same substances will be obtained—that the same increase in weight will be observed when, say, silver is combined directly with chlorine as when it is dissolved in nitric acid and the solution is precipitated with muriatic acid or salt. Silver is, therefore, heated in chlorine and is found to increase in weight to the same extent as when it is dissolved in nitric acid, etc.; a given weight of silver precipitated by salt is also found to increase to the same extent as when it is directly combined with chlorine. The composition of silver chloride having

thus been ascertained, the amount of chlorine in salt is determined. The composition of salt being ascertained, purified dried washing soda is converted into salt and also the amount of chalk gas which it contains is determined: from the data, the composition of sodium oxide may be calculated. In like manner the composition of lime may be ascertained by converting chalk into chloride by igniting it in hydrogen chloride and then determining the chlorine in the chloride; the same method may be applied to the determination of the composition of the oxides and chlorides of zinc, magnesium and copper.

Discussing these various results, and comparing the quantities of oxygen and of chlorine which combine with any one of the metals examined, it is seen that in every case about 35·4 parts of chlorine takes the place of eight parts of oxygen. Combination in *reciprocal proportions* is thus illustrated and by considering the composition of chalk and washing soda it may be shown that this applies equally to compounds of two and to compounds of three elements. As 35·4 parts of chlorine is found in every case to correspond to eight parts of oxygen, it is to be expected that hydrogen chloride contains one part of hydrogen in combination with 35·4 parts of chlorine; a solution containing a known weight of hydrogen chloride is, therefore, prepared by passing the gas into a tared flask containing water and the chlorine is then determined.

It being thus clearly established what are *equivalent* weights of elements, the conception of equivalents may be further developed by exercises in acidimetry carried out by the pupils themselves. The proportions in which washing soda and hydrogen chloride interact may be determined by mixing solutions of known

strength until neutralisation is effected; if the solution be evaporated and the chloride weighed, the results may be used in calculating the composition of hydrogen chloride; they serve, in fact, as a check on the conclusions previously arrived at as to the composition of washing soda and hydrogen chloride. Solutions of sulphuric and nitric acid may be similarly neutralised and, the amounts of sulphate and nitrate formed having been ascertained, the equivalents of the acids may be calculated on the assumption that the action is of the same kind as takes place in the case of hydrogen chloride. Determinations of the strengths of acids, etc., may then be made. In a similar manner the volumetric estimation of silver may be taught and the percentage of silver in coinage and other alloys determined.

Such a series of quantitative exercises as the foregoing, when carried out *before* and to a considerable extent *by* the pupils, undoubtedly affords mental discipline of the very highest order and is effective of good in so many ways that the value of such teaching cannot be over-estimated. The failure to grasp quantitative relationships which examiners have so frequently to deplore is without question largely, if not alone, due to students' entire ignorance of the manner in which such relationships have been determined. Moreover, the appreciation by the general public of the principles on which quantitative analysis is founded would certainly be directly productive of good in a multiplicity of cases.

STAGE VI.—*Studies of the physical properties of gases in comparison with those of liquids and solids. The molecular and atomic theories and their application.*

A series of quantitative experiments on the effect of heat on solids, liquids and gases should now be made, which should be followed by similar experiments on the effect of pressure; the similar behaviour of gases and the dissimilar behaviour of liquids and solids is thus made clear. The condensation of gases is then demonstrated and explained; also the conversion of solids and liquids into gases and the dependence of boiling-point on pressure and temperature. Regnault's method of determining gaseous densities is studied and the method of determining vapour densities is illustrated. The molecular constitution of a gas is now discussed; the phenomena of gaseous and liquid diffusion are studied and a brief reference is made to the kinetic theory of gases; then Avogadro's theorem is expounded and applied to the determination of molecular weights; and eventually the atomic theory is explained and the manner in which atomic weights are ascertained is brought home to the pupils. The use of symbols must then be taught. Finally, the classification of the elements in accordance with the periodic law should be explained.

It is all-important that at least a large proportion of the experiments in each of the stages should be made by the pupils; but even if this were not done and the lessons took the form of demonstrations, much valuable instruction might still be given.

The majority of pupils probably would not proceed to the fifth and sixth stages; but those who perforce

must terminate their studies without gaining any knowledge of chemical philosophy should unfailingly be led to make a few simple quantitative experiments: for example, to determine silver volumetrically; and the method of determining the composition of water and chalk gas should be demonstrated in their presence. And it may be added that if only the examples in Stages I and II and Problems I to V of Stage III were thoroughly worked out, most important educational training would be given and much valuable information as to the nature of common phenomena would be gained.

The complete course would undoubtedly take up considerable time but so does a satisfactory mathematical or classical course of study and it is absurd to suppose that useful training in science is to be imparted in a few months. If instruction be given in the manner suggested at all generally, it will be necessary, however, to modify the present system of testing results. Pupils could not be expected to pass at an early age examinations such as are at present held and awards would have to be based chiefly on an inspection of the classes at work and of note-books and on *viva voce* questioning. But all are agreed that the present system of payment on results tested by a terminal examination is a most unhealthy one and that a more rational system *must* be substituted for it. I may suggest that if members of the staff of science colleges, such as are now established in so many towns, could be appointed *supervising inspectors*, whose duty it would be to advise teachers in schools and *occasionally* to inspect the teaching in company with the permanent inspector, it would be possible to secure the assistance of a body of men who are in touch with

scientific progress and conversant with the improvements which are being effected. A man who "once an inspector is always an inspector" of necessity must get into a rut and will escape from the wholesome leavening and rousing influence which is always more or less felt by those whose office it is to follow the march of scientific progress.

It should also here be pointed out that the great majority of the experiments and exercises described may be carried out with very simple apparatus and with slight provision in the way of special laboratory accommodation. In but very few cases is there any production of unpleasant smells or noxious fumes. It is, in fact, a mistake to suppose that an elaborately fitted laboratory is in every case essential for successful teaching: much might be done in an ordinary school-room provided with a demonstration bench for the use of the teacher, a draught closet over the fireplace, a sink, a raised table for balances (raised so that the teacher might see what was going on), a cupboard for apparatus and a long narrow bench provided with gas-burners at which, say, twenty pupils might stand ten a side. At present the Science and Art Department will not recognise "practical chemistry" unless it be taught in a laboratory fitted up in a certain specified manner and their regulations are such as to enforce the provision of expensive laboratories in all cases where it is desired to obtain the grant. If greater latitude in fittings were allowed, more attention being paid to the character of the work done and less to the tools with which it is accomplished, probably much less money would be wasted by inexperienced school authorities in providing special laboratories and there would be much greater readiness displayed

to enter on the teaching of experimental science. The course which has been sketched out is one which doubtless might well be modified in a variety of ways according to circumstances. Thus many simple exercises in mechanics, in addition to those directly mentioned, might be introduced into Stage II, and the mechanical properties of common materials might be somewhat fully studied at this stage in districts where engineering trades are largely established and where such knowledge would be specially valuable. In like manner the physical effects of heat on substances might be studied in Stage III instead of Stage VI. And there are other chemical problems and simple exercises besides those described which might be substituted for some of them or included in the course.

Probably, however, it would be found undesirable, if not impossible, as a rule, to continue the teaching of chemistry proper much, if at all, beyond the stage indicated in this scheme. Other subjects will have a prior claim should it ever be deemed essential to include in a comprehensive scheme of school education the elements of the chief physical and biological sciences; it certainly is of primary importance to introduce at as early a period as possible the conception of energy and to explain the mechanical theory of heat, so that later on it may be possible to discuss the efficiency of heat and other engines; and until the laws of the electric current are understood, the subject of chemical change can never be properly considered.

In many cases, where it is convenient or desirable to continue the chemical studies, it probably will be advantageous as a rule that they have reference to

specific (local) requirements—*e.g.* to agriculture in schools in agricultural districts; to food materials and physiology in the case of girls especially, etc. But in any case more consideration must be paid, in the future, in schools where chemistry is taught, to educational requirements—the teaching must have reference to the requirements of the general public; and it must be remembered that the college, not the school, is the place for the complete study of a subject.

XVII

EXERCISES ILLUSTRATIVE OF AN ELEMENTARY COURSE OF INSTRUCTION IN EXPERIMENTAL SCIENCE

THE scheme put forward in the report presented last year by the Committee sufficed to indicate the kind of instruction likely to inculcate habits of observing correctly, of reasoning from observation and of setting new questions and obtaining answers thereto by experiment and observation: habits which it is now generally admitted are of great consequence in the struggle for existence and which cannot be acquired except through training in the methods of experimental science. Nevertheless, it has been felt that detailed directions how to proceed were necessary for the use of the less experienced teachers and that even those who fully sympathise with the proposals already made would welcome the more complete display of the system. I have therefore obtained the permission of the Committee to append the following suggestions to their report, in amplification of certain parts of the scheme already published.

It is obviously impossible to sketch more than a small portion of a complete programme of instruction; the portion now offered is that appropriate to the

earliest stage in which quantitative studies can be engaged in: its study can be commenced by children of fair intelligence when 9 or 10 years old. It is an essential feature of the scheme that it has reference to common things, the object being to lead children to engage in the rational study of the objects which are daily brought under their notice.

Time to be devoted to Experimental Studies and Mode of Teaching.—Frequently during the past year the question has been put to me, "How much time is to be devoted to such science teaching?" and complaint has been made of the difficulty of dealing with large classes of children, of keeping them employed and of providing the requisite space and appliances.

The question as to time will ever continue to be put until the fundamental fallacy which hitherto has retarded the progress of experimental teaching in schools is discarded, viz. that sufficient training in a scientific subject can be imparted in the course of a term or two. This undoubtedly is the view entertained in the majority of schools—girls' schools in particular. It is well known, for example, that of the many hundred students who each year present themselves at the London University Matriculation examination, the vast majority have had but a *few months' coaching* in chemistry, mechanics or physics, although they have had lessons in arithmetic and like subjects during the *whole period* of their school career. It was long a superstition that to pass in chemistry all that was necessary was to have read some one of the small text-books and a very large proportion of matriculants have doubtless had only such preparation. The fact is that our schools hitherto have been all but

entirely in the hands of those who have had a purely classical or mathematical training and who have gained their knowledge by reading; teachers thus trained cannot realise that the useful effect of science teaching is only attained when the instruction is carried out on entirely different lines: they cannot realise that *accurate experimenting* is the essential feature in the system; that knowledge gained by mere reading is and can be of little use, as in acquiring it the mental faculties which it is desired to exercise never become trained. It must be recognised by all who have charge of schools that, in order to secure the due development of those faculties which science teaching alone can affect, the instruction must be imparted *from the very beginning and during the entire period of the school career.*

If this be done, many of the difficulties hitherto encountered may disappear. Probably it will be found advantageous, at least in the earlier stages, rather than disadvantageous, to devote but a short time during any one lesson to actual experimental work. There is no doubt that far too much is usually attempted; that too many facts are brought under the student's notice in the course of the lesson, the result being a blurred mental picture destitute of sharp outlines. After considerable experience I am satisfied that it is difficult to proceed too gradually—it may almost be said too slowly.

The following two sets of instructions are given by way of illustration; it is not pretended that they are complete nor is it suggested that the exercises should be worked through either exactly in the order in which they are stated or completed by all pupils; the teacher

must determine which are suitable for the particular set under instruction.

Studies of Water and Common Liquids

1. Make every effort to elicit from the pupils by question and answer all that *they* have noticed with regard to water. Induce them to take advantage of any opportunities the neighbourhood affords of observing water and its effects. Let them ascertain the area covered by the school-house roof and the amount of water which falls on it when it rains; institute systematic observations of rainfall and embody the data in arithmetical exercises. Call attention to the different yearly rainfall in different parts of the country and point out the influence of hills and mountains: let outline maps be coloured, so as to indicate the different rainfall of different districts.

2. Call attention to the geographical distribution of water, etc.; also to the work which it does in nature (cf. Geikie's *Physical Geography*, Huxley's *Physiography*, etc.), illustrating this part of the subject—especially at an inland school—by lantern photographic slides of ships, sea-coasts, Niagara Falls, etc.

3. Call attention to the disappearance of water, *i.e.* the drying up of rain, the drying of clothes, etc., and lead the pupils to notice that this takes place most quickly in hot weather and in warm places; then let them pour water into a clock glass placed either over a saucepan in which water is boiled by a gas-burner (or petroleum or spirit lamp, if gas be not available), or in a small gas cooking-stove; they will see that the water evaporates, leaving a certain amount of *residue*. [At this stage experiment on the extent to which water

evaporates out of doors and indoors under different conditions and at different times of the year by exposing water in weighed glass (crystallising) dishes about 4 inches in diameter and weighing at intervals. Also call attention to the fact that in certain states of the weather things become damp and that moisture is sometimes deposited on the windows in cold weather; then let the condensation be noted of a liquid indistinguishable from water which occurs, for instance, when a closed flask filled with water and ice is exposed in a room. Let some seaweed enclosed in a muslin bag be hung up out of doors where it cannot be wetted by rain and have it weighed daily. At the same time have the temperature, direction of the wind and character of the weather noted. Later on have the dry and wet bulb thermometer read daily. Have the changes in weight of the seaweed and the dry and wet bulb thermometer readings represented by curves. Lead the pupils to contrast and discuss the results.] The experiment should then be repeated with a known quantity of water and a weighed glass dish, so as to determine the amount of residue; the character of the residue should be noticed. Discuss the origin of the water and point out whence the residual matter *may* have come. Next, if a well water was taken, let a local river or pond water be examined in a similar way, then rain water and, if possible, sea water.

4. Let an ordinary 2-oz. narrow-mouth stoppered bottle, having a nick filed down the stopper, be filled with each of the waters and weighed; and let the operation be repeated several times with each water, so that the *experimental error* may be ascertained; it will be found that the different waters, sea-water excepted, have practically the same *density*. At this

stage, arithmetical exercises relating to the weight of known bulks and *vice versa* of water, the quantities of dissolved solids present in given bulks of various waters, etc., may advantageously be set; these should be solved practically by actual measurement in as many cases as possible.

5. Next ask, "But what becomes of the water when driven off by heat?" If it have not been noticed that water collects (condenses) on some object near at hand, let a cold object be held over boiling water, then let water be boiled in a glass flask connected with a glass condenser. Afterwards have water distilled in larger quantity from a tin (2-gallon) can. The density of the distilled water should then be determined and its behaviour on evaporation. Data would thus be accumulated rendering it possible to explain the drying up of water under ordinary conditions, the origin of rain, the differences between waters from various sources and the method of separating water from the associated foreign matters will have been brought home to the minds of the pupils.

6. As the water is heated to boiling in the flask, if attention be paid to all that occurs, it will probably be noticed that bubbles separate from the water, rising up through it and escaping at the surface; frequently the bubbles adhere for a time to the flask. Let the experiment be repeated in such a way that the something which escapes from the water can be collected and measured; for example, a 2-gallon tin can having been filled with water, insert into the neck a rubber cork through which a bent *delivery tube* is passed, place the can over a burner, introduce the upturned end of the delivery tube into a basin of water and insert a small jar over it. Heat to boiling. An air-

like substance will gradually be driven off but it will be noticed that after the water has been boiling for some time it ceases to give off gas; let the amount of gas collected be measured and have the experiment repeated several times. As the gas does not continue to come off on boiling the water, it would seem that it is not a part of the water—there is so little of it—but merely something dissolved in the water; it is like air, as the water had been in contact with air—may it not be air? Let the boiled water be poured out into a galvanised iron pan and after it has been exposed to the air for several hours let it be again boiled. The water which previously no longer gave off gas will probably now yield as much as before. It will thus be discovered that water dissolves air as well as the solid matters with which it comes in contact and the presence of air in water will be recognised. This knowledge will be of value later on when the existence of animals and plants under water comes to be considered.

7. Attention having thus been directed to the solvent action of water, let special experiments be made on its solvent action, using salt, sugar, suet, washing soda, alum, tea and coffee, field or garden soil, clay, chalk or limestone, gypsum, etc.; known quantities of the filtered solutions should be evaporated to dryness and the residues dried (conveniently in a small gas cooking-oven) and weighed. Opportunity will be afforded to call attention to the separation of some of the substances from solution in definite shapes, *i.e.* crystals; show these under the microscope as well as home-made cardboard models of some of them. Let larger crystals of alum be grown and call attention to sugar crystals. Natural crystals of calcite, gypsum,

pyrites, quartz, fluorspar, etc., would be appropriately shown at this stage. The question may then be put, "Does the water which passes through the body dissolve anything?" By evaporating urine and determining the amount of dried residue it would be found that a good deal of matter passes away from the body in solution.

8. Having directed attention to the different behaviour of different waters with soap, let determinations be made of the amount of alcoholic soap solution required to produce a lather in distilled and other waters. Directions for performing the soap test are easily obtained from a book on water analysis and the operation is one of extreme simplicity.

9. Other liquids should now be compared with water, such as methylated spirit, turpentine, petroleum, salad oil, vinegar and perhaps the common acids—muriatic, nitric and sulphuric—also. The noticeable differences between these and water — appearance, odour, taste in dilute solution—having been registered, their relative densities should be determined; also their behaviour towards water and towards each other, their behaviour when heated on the water-bath in comparison with that of water, their behaviour when burnt, their behaviour when boiled together with water in a flask attached to a condenser and their solvent action in comparison with that of water should be ascertained.

10. Having given an account of the origin, etc., of the various liquids examined and having alluded to the presence of alcohol in beer and wine, demonstrate the separation of alcohol from beer by distillation; then describe the production of alcohol by fermentation and carry out the experiment, first with sugar and yeast,

then with malt; explain that yeast is an *organism*: either show it under the microscope or enlarged photographs of it. Make several mixtures of alcohol and water and let the relative density of each be determined; then exhibit a table of relative densities of spirit solutions of various strengths. Let a measured amount of beer be distilled, have the distillate made up with distilled water to the bulk of the beer taken and let its density be determined; reference being then made to the table of relative densities, the strength of the alcoholic distillate could be ascertained and thus the amount of alcohol in beer would be determined.

11. The behaviour of water when heated may now be further studied. Attention having been called to the thermometer as an instrument which enables us to judge degrees of heat, water should be heated and the gradual rise of the mercury column of the thermometer noted, as well as the steady position which it assumes when the water boils. In the same way boiling water should be allowed to cool and the fall of the mercury column noted; further cooling should then be effected by means of ice, so that opportunity might be given for the stationary position to be observed which the column eventually takes up and maintains so long as unmelted ice is present. Having specially directed attention to these "fixed points," describe the construction of the thermometer. Next let a quantity of water be distilled from a flask or can having a thermometer in its neck and let the steady position of the mercury throughout the distillation be observed. Also let water be frozen by means of a mixture of ice and salt; the "temperature" of the freezing mixture having been ascertained, the thermometer bulb should be inserted into the water which is being frozen (in a test tube), so that

the ice may form around its bulb; the temperature should be noted during freezing and also during the subsequent melting of the ice. Do this out of contact with the refrigerating mixture.

12. Let the relative density of ice be determined, *i.e.* after showing that although "lighter" than water ice is "heavier" that turps, let a cylinder partly filled with turpentine be counterpoised and after the temperature has been lowered by immersing the cylinder in ice water, note the position of the turps, then introduce a few pieces of dried ice, note the rise of the turpentine—thereby determining the volume of the ice—and subsequently weigh in order to ascertain the weight of ice introduced. Have the result thus obtained checked by subsequent observation of the bulk of water which is obtained when the ice melts. The expansion of water on freezing having thus been observed, the bursting of pipes in winter may be explained; and attention may also be directed to the destructive effects on rocks produced by the freezing of water; the extent to which ice floats may be discussed and arithmetical problems may be set which will lead the pupils to realise the extent to which the volume changes when water changes its state.

13. Let the relative density of water and the other liquids be determined at 0° C. and at a higher temperature—that at 0° by weighing and that at the higher temperature by observing the expansion of the liquids in bulbs with graduated stems of known capacity—let curves be constructed showing the relation between temperature and volume.

14. Let spirit, turpentine, petroleum and vinegar be distilled; the temperature during distillation being observed, the gradual rise especially in the case of

spirits and petroleum will be noted. Fractionally distil several times some quantity of spirit and of petroleum; let the relative density of each separate fraction be determined and let the water separated from the spirit be characterised by freezing it and determining the melting-point of the ice and the boiling-point of the liquid which is obtained when the ice melts.

15. Having directed attention to the fact that heat is "used up" in melting ice and boiling water, let determinations be made of the amounts, following Worthington's *Practical Physics,* for example.

Studies of Chalk and other Common Solids.

1. Call attention to the use made of lime in building and its production from chalk or limestone; slake a lump of lime; exhibit specimens and pictures of chalk cliffs or quarries and limekilns—if not to be seen in the district. Point out on a geological map those parts of the country in which chalk occurs and those where limestone is met with. Explain how chalk is supposed to have been formed; show pictures of the forms which are present in it—if possible, microscopic slides. Explain that whitening, which is purchasable everywhere, is but lævigated chalk, describe its preparation and let chalk and sand be separated by lævigation.

2. Let the conversion of chalk into lime be studied quantitatively. For this purpose 3 to 5 grams of dried whitening should be weighed out in a small platinum dish and heated to full redness in the *covered* dish during an hour over a Fletcher-Argand-Bunsen burner: the dish is then removed from the burner; after about ten minutes, when cold, it is weighed;

the bottle A. The cork having been inserted, connection is established by means of the flexible tube C with the bottle D. The side tube E having been so adjusted that the end *e* is on a level with the water in the bottle D, the measuring cylinder H is so placed that any water which runs from *e* may be collected in it

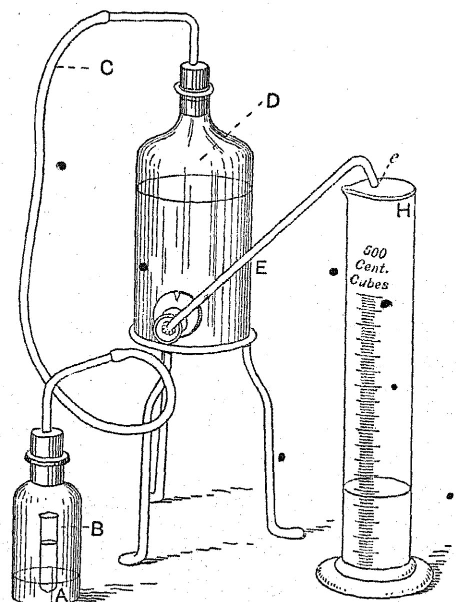

FIG. 1.

and the bottle A is then carefully tilted so that the acid may gradually run out of the tube B into A; gas is at once given off and expels water from D. As the water sinks in D the side tube E is lowered so that its orifice remains about on a level with the water in D. The water is then measured. Several experiments should be made and the results should be

compared by calculating the volume of gas which would have been obtained, supposing, say, 100 grams of the chalk had been dissolved.

5. In this way it is ascertained that *chalk-stuff* is *characterised* by (1) yielding between 56 and 57 per cent. of lime, which increases by about 33 per cent. when slaked; and (2) by yielding about 22,000 cubic centims. of chalk-gas per 100 grams when dissolved in acid.

6. Comparing lime with chalk, it is found that if the chalk be thoroughly burnt no gas is evolved on dissolving the recently slaked lime in acid; this result serves at least to suggest that the gas which is given off when chalk is dissolved in acid is perhaps expelled during the conversion of chalk into lime. The loss in weight which occurs is therefore determined and when it is ascertained that it is very nearly the same as that which chalk suffers when burnt, no room is left for doubt that the same substance is dispelled by heating and by dissolving the chalk in acid. The experiment is very easily carried out in a small bottle or conical flask provided with a tube to contain acid and closed by a cork through which pass a narrow tube bent at a right angle and a small drying tube full of cotton wool. The chalk is weighed out on thin paper and dropped into the flask, a little water is poured on to it and the acid tube is then introduced, after which the cork is inserted. The bent tube is closed by a small stopper. On tilting the flask, acid escapes and attacks the chalk; the spray is prevented from escaping by the cotton wool. When the action is at an end, air is sucked in through the narrow bent tube to displace the chalk-gas; finally the loss in weight is determined. Such an apparatus gives admirable results.

7. Marble may then be examined in a similar way; as it is found to behave both on heating and when dissolved in acid much as chalk does, it may be presumed to consist of chalk-stuff. Next, limestones should be taken; the result obtained with them may be lower owing to their containing clay, etc.; but this is to a large extent rendered evident by insoluble matter left on treating with acid. Let the percentage of chalk-stuff in the limestones be calculated from the results which they afford, assuming the results obtained with chalk to be practically those afforded by pure chalk-stuff. Lastly, direct attention to the occurrence of crystals (calcite) in limestone rocks, to stalactites, etc.; show specimens and have them examined: the results will show that they also consist of chalk-stuff.

8. Having pointed out that chalk consists of shells, etc., of sea-animals, coral and shells of various kinds—oyster, cockle, limpet—should be given for examination; all these will be found to give results from which it may be inferred that for the most part they consist of chalk-stuff. Egg-shell and lobster or crab shell, in like manner, will be found to yield lime when burnt and to behave much as chalk does towards acid; but the presence of a certain amount of "animal" matter will be evidenced by the blacking on heating and the insolubility of a certain proportion in acid.

9. Ordinary bone, gypsum, clay and rocks other than chalk or limestone rocks are next given for study, in order that it may be discovered that the behaviour of chalk-stuff is peculiar and characteristic and that there are many varieties of natural solids. Rough estimates of the amount of chalk in soil may be made by determining the amount of chalk-gas evolved on treating the soil with acid.

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10. In a hard-water district, the residue from the water will probably look more or less like chalk; its behaviour when heated with acid and when strongly heated should therefore be determined and local boiler or kettle scale should then be studied as chalk was previously.

11. In this manner, a large number of data will be accumulated which render it possible to discuss the origin of chalk, to explain the presence of chalk-stuff in water and its withdrawal from water by animals, etc.

The study of chalk in the manner indicated would make it possible for the student (1) to comprehend the principle of the method followed by chemists in characterising substances whereby they are led to discover distinct forms or species; (2) to realise not only that there are *compounds* but also that such substances have a fixed composition; and (3) the entire difference in properties between a compound and its constituents would have been brought out most clearly by comparison of chalk-stuff with its constituents — lime and chalk-gas. The chalk studies, in fact, should serve to incite the student's curiosity and should lead to further inquiries being undertaken as to the composition of other substances and the characters of their constituents and as to the nature of other changes; and with regard to the method of undertaking inquiries into the composition of other substances, the important results obtained in the case of chalk by studying the *changes* which it undergoes would serve to illustrate the importance of studying change as a means of determining composition.

It cannot be denied that only well-informed,

thoughtful teachers could give useful instruction in accordance with the foregoing schemes; but this is scarcely an objection. The amount of special training required to carry out the experimental portion would not, however, be great; and there is no reason why such instruction should not be given in schools where there is no special science teacher engaged—although the services of such a teacher would undoubtedly be necessary if instruction in accordance with the more complete scheme embodied in the report presented last year by the Committee were carried out in its entirety.

The suggestion that it will probably be found advantageous at least in the earlier stages, rather than disadvantageous, to devote but a short time during any one lesson to actual experimental work (cf. page 346) would be realised in practice if the experimental science lesson were associated with the measurement or practical arithmetic and drawing lessons; and it is difficult to imagine that this is not possible. Suppose a set of twenty-four pupils to be at the disposal of a teacher during an entire morning or afternoon, in a properly appointed room of sufficient size, and that they are set to work to carry out the experiments with chalk, described on page 355. Several—say six —might be told off to weigh out in platinum dishes the necessary quantities of whitening and having then placed the dishes on Fletcher burners or in a muffle, they would return to their places; at the end of an hour they would remove the dishes and after leaving them during ten minutes to cool would weigh them. To determine whether any change took place on further heating, they would reheat the dishes during say half an hour, at the expiration of which time, as soon as

the dishes were cool, they would weigh them again. As soon as the first set of six had weighed out the chalk, a second set of six might be set to work in a precisely similar way if the necessary apparatus were available; if not at some other exercise involving the use of the balance.

The nature of the experiments which each set were engaged in performing should be made known to the whole class and all the data should be written up on a blackboard. Each pupil should write out an account of the experiments and of the results; opportunity would thus be given to compare the results of the six or twelve separate experiments. At the next lesson the two remaining sets of the class would carry out the same experiments. Each pupil would thus have the advantage of performing one or other of the experiments and of knowing what results had been obtained by a number of fellow-students. If necessary, two pupils might be set to perform one experiment, care being taken that they took equal parts in it; and thus the whole class of twenty-four might complete the experiment or experiments in a lesson.

Those of the class who at any time were not actually engaged in carrying out the experiment might be occupied in other ways, *e.g.* in measuring distances, in drawing figures of stated dimensions, etc., in determining areas, in determining relative densities, in working out arithmetical problems or in writing out notes and answers to questions. It would not be difficult as the class progressed to devise an infinite number of problems and exercises the data for which were derived from experiments performed by the class.

If only one such lesson were given per week, a single teacher and an assistant might deal with 240

pupils or with half that number if each class had two lessons per week—a much better course; working on a similar plan, much useful work might be done even in the course of two hours.

With regard to the appointments for such work, the schoolroom should be provided with simple working benches in addition to the ordinary desks and forms. A narrow table might be placed across one end of the room—preferably on a raised platform—at which the teacher could sit and on which the balances could be placed; the teacher would then be able to supervise the weighing and secure that due care were taken of the balances. A narrow bench (of deal, into which paraffin had been "ironed," so as to waterproof it) might be fixed against and along the wall at either side of the room. This should be fitted with simple cupboards and drawers for apparatus and if possible with gas taps; and at a suitable distance from the wall and above the table there should be a bar, carried by brackets affixed to the wall, from which various apparatus, small scales, etc., could be suspended. A simple draught arrangement should and might easily be fitted at each working place, so that no unpleasant or noxious fumes need escape into the room. At the other end of the room it would be desirable to have a demonstration table and behind this, against the wall, a draft closet at one end of a bench at the other end of which was a capacious sink. It would be well also to have a sink within the closet, which could be made use of, for instance, in washing out a sulphuretted hydrogen apparatus. A muffle furnace at the side of the ordinary stove would be a most valuable adjunct.

The cost of carrying out experiments such as have been suggested remains to be considered.

The chief item is undoubtedly the balance. Useful work may be done at a very early stage of the measurement lessons with scales costing five or six shillings, as suggested by Professor Worthington; but their use for quantitative chemical work such as is comprehended in the foregoing scheme is entirely to be deprecated. The acquisition of the habit of weighing carefully and

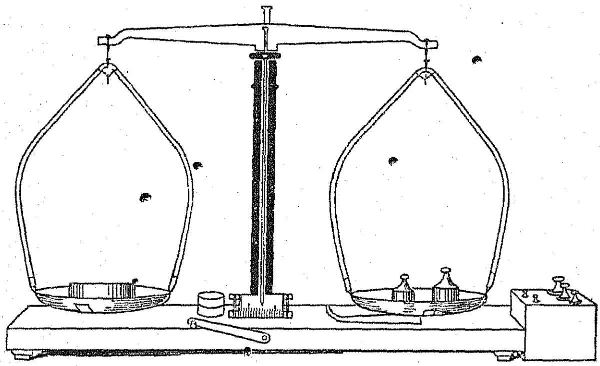

FIG. 2.

exactly is in itself a discipline of the utmost value, to which every boy and girl should be subjected. It is all important, therefore, that a fairly good balance should be used and that the utmost care in its use should be enjoined. When not in use the balance should be covered over with a cardboard box. Becker's No. 51 (Fig. 2) and No. 67 balances, to be had from Townson and Mercer, the English agents, are to be strongly recommended, the former being probably the more suitable as the pans are carried by "bowed" wires, giving more room for manipulation, when, as in

determining relative densities by the hydrostatic method, a bridge to carry a glassful of water is placed across the scale-pan. No. 51 costs £1 : 17 : 6; No. 67 £2 : 1s. A suitable set of weights (No. 31), from 500 grams downwards to centigrams, costs 18s. 4d. Even if six balances were provided—and such a number would suffice for a large class—the cost would be but £18.

A convenient size of platinum dish to use is one about $\frac{3}{4}$ inch deep and 2 inches wide, weighing, with a light cover, about 20 grams. At a normal price of platinum such a dish would cost about 25s., so that a considerable number might be provided for an outlay of £10. Such dishes last a long time when properly used, and are still of value when damaged (Note A).

A water oven for drying would cost about £1; one of Fletcher's small air ovens for drying costs 17s. 6d.

Fletcher's Argand Bunsen burners, with tripod, are to be recommended as superior to the ordinary burners for school work. The smaller size costs 2s.; the larger 3s. Suitable black rubber tubing for use with these burners, $\frac{3}{8}$ inch in diameter, costs about 9d. per foot. A pair of iron crucible tongs costs 1s.

The apparatus for measuring the gas evolved on dissolving chalk in acid would cost about 7s., including a 500 cubic centim. measuring cylinder.

Glass basins about 3 inches in diameter cost 4d. each; clock glasses, 6 inches in diameter, 5s. per dozen.

50 cc. burettes cost 3s. 6d. each.

It is unnecessary to refer to the cost of the few remaining articles required for the suggested experiments, as they are well known. An expenditure of £50 would certainly cover the cost of apparatus

required by a class of, say, twenty-four; and this would suffice for the use of several such classes.

NOTE A.—The unfortunate rise in the price of platinum, which makes the purchase of any number of platinum vessels for school use out of the question, has led me to make a number of experiments in the hope of substituting silver; but, as was to be expected, this has proved to be impossible. I find, however, that porcelain may be used, provided that the heating be effected in a muffle furnace. Small thin hemispherical porcelain capsules may be obtained from the dealers, about the size of the platinum dishes specified, which are more suitable than porcelain crucibles for the experiment. Such dishes may also be used in studying the effect of heat on organic substances, the char being burnt in the muffle furnace.

XVIII

THE TEACHING OF SCIENTIFIC METHOD

IN order that children may acquire scientific habits, they should be led to look around them and take note of all the various objects which present themselves to view; lists of such objects having been prepared, their several uses having been as far as possible understood and much simple information as to their origin, etc., having been imparted by reading lessons and practical demonstrations, a stage will be reached at which the children can themselves begin to determine the properties of common objects, generally by *measurement*. The measurement lessons in the first instance may be of the simplest kind. Much may be done with the aid of a boxwood scale divided into tenths of an inch on the one edge and into millimetres on the other; with the aid of such a scale; children may learn to measure accurately and may be taught the use of decimals and the relation between the English and the metric system. Obviously such work might well form part of the arithmetic lesson and there can be no doubt that "practical arithmetic" lessons would often be far more easily mastered and be more interesting than are the dry problems of the books. It is easy also to take advantage of the opportunity afforded by these lessons to impress useful information.

Measurement lessons may take the form of lessons in weighing. I am of opinion that the disciplinary effect of teaching children to weigh exactly cannot be overestimated; it matters little what is weighed, provided that the weighing be done as accurately as the balance at disposal permits. Prof. Worthington, in his invaluable book *Physical Laboratory Practice* (Rivingtons), has advocated the use of a simple balance costing only 4s. However suitable this may be for demonstrating certain principles in physics, its use is entirely to be deprecated, in my opinion, for the purpose I have in view; I would urge most strongly that a far better instrument be procured, such as one of Becker's (*of Rotterdam;* English agents, Townson and Mercer) balances, costing, with suitable weights, about £3. In using such a balance, care has to be taken in releasing the beam and in bringing it to rest again; the pans must not be allowed to swing from side to side but must be made to move gently up and down; the weights must be lifted on and off the pans with pincers, not touched by the fingers, so as to preserve them untarnished; and the weighing can and, in fact, must be made with considerable exactness. Finding that so many precautions have to be taken and being severely reprimanded if careless in using such a balance, the child acquires a wholesome respect for the instrument and soon becomes careful and exact. Weighing with the four-shilling pair of scales can afford no such discipline; their use in no way serves to correct the tendency—to quote a schoolboy phrase—to "muck about," unfortunately inherent in youth; a tendency which can, I believe, be more successfully counteracted by proper measurement lessons than in any other way. The objection made to the purchase

of so costly a balance for school use, I hold to be quite unwarrantable; schools have no hesitation in charging for the use of books and a charge of half a crown a year would more than cover their cost, if it were not possible to provide weighing appliances as part of the school furniture. I have been told that you cannot trust boys to use so delicate an instrument as that I advocate; and probably you cannot, if you wait until they have grown past control: but I believe that the difficulty will not arise if the instruction be given to children when quite young.

Having learnt to measure and weigh exactly, the children may be set to examine things generally. One of the best exercises that can be devised consists in weighing and measuring rectangular blocks of different kinds of wood and then reducing the results so as to ascertain the weights of equal bulks: in this way the child is led to realise that in the several varieties different amounts of the wood-stuff are packed into the same space; that some woods are *denser* than others. The *relative densities* may then be calculated, taking the lightest as standard; and also their *densities, i.e.* the quantity of wood-stuff in the unit of volume, choosing several different units both of mass and of volume. The data thus obtained may be made use of in many ways, *e.g.* in setting arithmetical problems as to the weights of planks, etc., of various sizes; and lessons may at the same time be given as to the uses and characters of the different woods, the trees from which they are obtained, etc. In a similar manner, common liquids may be studied comparatively with the aid of a simple "density" bottle, constructed by filing a nick down the glass stopper of an ordinary 2 oz. narrow-mouth bottle, which may also be used in

determining the relative density of solids of irregular shape. Children are thus put in possession through their own efforts of a series of numerical data whereby various materials may be characterised and can be led to understand that it is possible to convey exact information by quoting these numerical data.

It is almost superfluous to point out that when the use of the balance has been learnt, a stage is reached at which the study of levers and other simple mechanical powers may very properly begin; and that the determinations of densities of liquids serve as an appropriate introduction to Hydrostatics.

Measurements of another kind, which afford most valuable training, are those effected with the aid of a thermometer. It is most important that the use of this instrument should be generally understood—especially by women. It is astonishing how few people know the temperature at which water boils; and how mysterious an instrument to most is the clinical thermometer. Practice having thus been acquired in making measurements and considerable knowledge having been gained of properties of common materials, I would advocate the quantitative study—especially by girls—of the effect of heat on vegetable and animal food materials and subsequently on earthy substances and metals: such exercises would serve as an appropriate introduction to the study of chemical change, which at this stage should be entered on more particularly with the object of developing the reasoning powers. I propose to give two examples by way of illustration—the one relates to the discovery of the composition of air; the other to the discovery of the composition of chalk.

In considering air, it is the practice with most

teachers, I believe, to explain, and in some cases demonstrate, how oxygen may be prepared and how brilliantly many substances burn in it; air is then *stated* to be a mixture of oxygen with nitrogen in certain proportions and certain *proofs* of this statement are advanced. Although much interested in the statements and delighted at witnessing the firework displays which attend combustion in oxygen, the young student is not much the wiser for such lessons: a certain amount of "prepared food" has been put into his or her mouth but no understanding acquired as to how it has been prepared or whence it came. I advocate an entirely different course: I would not say one word as to what air is or as to its having anything to do with combustion but would lead the scholar to discover that air is concerned in many common changes which apparently occur spontaneously and to understand how the discovery that this is the case is made. Having directed attention—to the manner in which animal and vegetable substances gradually decay and are destroyed when burnt—to the rusting of iron, etc., I would propose that such changes should be experimentally investigated and suggest that as iron rusts so readily when moist, the rusting of iron should be first examined; then would come the question, "But how is this to be done?" Having become so habituated to the use of the balance and to express facts by numerical data, the student would appreciate the advice, "Let us see whether the balance will not aid us; let us endeavour to ascertain whether the iron gains or loses in weight during rusting." A clock glass or saucer is therefore weighed; some iron borings or nails are put upon it and the weight ascertained; and as iron is known to

rust more rapidly when wet, the borings or nails are wetted and set aside to rust. After several days the rusted iron is dried in an oven and weighed: it is found that the weight has increased, whence it follows that *something from somewhere* has been added to the iron. Thus a clue has been gained and following the example of the detective in search of a criminal this clue is at once followed up. "Where did the something come from? It might be the water: but is there no other possible 'offender?' Yes—the iron rusted in air." This suggests the experiment of exposing wet iron in air in such a way as to ascertain whether the air is concerned in the rusting. Some borings are tied up in a piece of muslin and the bag is hung from one end of a piece of stout wire, bent round at the opposite end so as to form a foot; the wire is set upright in a dish full of water and a large pickle jar is inverted over it, the mouth of the jar in the water. The iron is thus shut up over water along with air. Gradually the iron rusts and concurrently the water rises in the jar—showing that the air is concerned, as no rise is observed in a comparison experiment without the iron. But after a time the water ceases to rise; measurement shows that only about one-fifth of the air disappears. Clearly, therefore, the air is concerned. The experiment is repeated and the same result obtained; fresh iron is put into the residual air and still no change results: hence it follows, that although the air plays a part in the rusting of the iron, the air as a whole is not active but only one-fifth part of it, which serves to suggest that the air is not uniform but has parts. Consider the importance of the lesson thus learnt; the number of discoveries made by a few simple quantitative

experiments; the insight into exact method which is gained by a thoughtful worker.

To pass to my second example — the discovery of the composition of chalk: how is this to be effected? I would call attention to what is known about chalk by people generally—what it is like, where it occurs and what it is used for and ask whether there is no well-known fact connected with chalk which will serve as a clue and enable us to apply our detective's method. One of the great uses of chalk is for making lime, which is got by burning chalk. Is there anything known about lime which shows that it differs from chalk? Yes, when wetted, it slakes and much heat is given out, whilst chalk is not altered by wetting; when the experiment is made quantitatively, lime is found to increase about 33 per cent in weight on slaking. Let us then study the conversion of chalk into lime by burning and as our unaided eyes tell us nothing, let us call in the aid of a balance. A weighed quantity of chalk is strongly heated and is found to grow lighter; after a time, no further loss is observed and when this is the case, the loss amounts to, say, about 43 per cent; on repeating the experiment, the same result is always obtained and therefore it cannot be an accident that the loss amounts to only about 43 out of every 100 parts of chalk. What conclusion are we to draw? Evidently that the stuff composing chalk consists of lime-stuff plus something else which is driven off when the chalk is burnt. What is this something—can't we catch it as it is given off? [We can, but the experiment is difficult, requiring special appliances, owing to the higher temperature required to burn chalk in a close vessel.] If not, is there no

other clue which can be followed? Yes, there is. It is to be supposed that at an earlier stage in the experiments attention will have been directed to the way in which discoveries were made in early times: to the fact that various substances were found to act on each other, giving new substances; and that when a new substance was discovered its action on the previously known substances was studied. That in this way various acids were discovered; and that it was found out that these were powerful solvents of metals, earthy substances, etc.,—of chalk, among other substances. What happens to chalk when thus dissolved in an acid? The experiment is tried and it is found that an air-like substance or gas escapes as the chalk dissolves. How does lime behave with acid? It is found on trial to dissolve but no gas is given off. May it not be then that the gas which is given off when chalk becomes lime is also given off when chalk is acted on by acid? Let us find out how much gas is given off in this latter case. A weighed quantity of chalk is dissolved in acid and the gas measured, a simple apparatus being used, like that figured in the last British Association Report (that shown on p. 357); it is found, when several experiments are made, that, on the average, about 22,000 cubic centimetres of gas are given off per 100 grams of chalk—chalk is thus shown to be characterised not only by the percentage of lime which it yields but also by the amount of gas which it affords when dissolved in acid.

What is the weight of the gas that escapes? The experiment is carried out [by means of a very simple apparatus] and the all-important discovery is made that the weight of the escaping gas is just about what

was lost on burning chalk. There can be little doubt, therefore, that the gas thus studied is "the something" which is given off when chalk is burnt. If so, perhaps it may be possible to reassociate this gas with lime and produce chalk. Lime is therefore exposed in an atmosphere of the gas and the increase in weight determined; it is eventually ascertained that the lime increases in weight to the extent required on the assumption that it is reconverted into chalk and on examining the product it is found to behave as chalk both when heated and when dissolved in acid. Thus the problem is solved and it is determined that *chalk-stuff* consists of *lime-stuff* and *chalk-gas:* I employ these terms advisedly and advocate their use until much later a stage is reached when systematic nomenclature can be advantageously made use of.

In talking about chalk, it may be pointed out that chalk is believed to consist of skeletal remains and shells of sea animals and when the composition of chalk has been ascertained the suggestion comes naturally to examine shells. When their behaviour on burning and towards acid is studied quantitatively, results are obtained which place it beyond doubt that they consist essentially of chalk-stuff. The chalk studies thus become of very great importance and may be made to cover a wide field.

It is not to be denied that there are difficulties connected with such teaching as that I am advocating but it is a libel on the scholastic profession to assert that the difficulties are insuperable. I am sure that in this case the old ever-true saying may be quoted: "Where there's a will there's a way." Such teaching has not yet been given simply because there has not

yet been the will to give it; because its value has not yet been appreciated.

But there must be less class teaching, more individual attention; an adequate proportion of the school time must be devoted to the work; and properly trained, sympathetic teachers must be called in to give such instruction.

When scientific method *is* taught in schools, there will inevitably be a great improvement in school teaching generally; it will be carried on in a more scientific manner and new methods will be introduced. Indeed, I have already learnt from a headmaster in whose school experimental science teaching is receiving much attention, that the leavening effect on the teachers of some other subjects in the school is quite remarkable and that they are clearly being led to devise more practical modes of teaching.

Photography and the lantern, also, are modern weapons of great power, which often enable us to clothe the dry bones of otherwise unattractive subjects with pleasing drapery. And here the parent can often intervene with great effect.

XIX

HOW SCIENCE MUST BE STUDIED TO BE USEFUL

There is but one way of studying science properly—that is, to come personally into contact with the facts. And my first duty as a lecturer is to warn you against merely attending lectures for the purpose. Lectures only become of real value when those who hear them know a good deal of the subject already. I am satisfied that if freely indulged in during early studies they are, as a rule, productive of much harm. The knowledge of method and the discipline afforded by laboratory studies are factors of primary importance which meet with no consideration in a lecture course.

Attendance at lectures may almost be said to be a fashionable craze of the day—they are certainly frequented by many as a mild and moral form of entertainment, affording opportunity of indulging in intellectual dissipation in a manner which is peculiar to this country. And, still more remarkable, persuading ourselves into the belief that we have learnt something, after attending them, we offer ourselves up for examination with an ardour which the Chinese can scarcely rival; and examiners pocket their consciences and write complimentary reports on the results. Still

more serious is the fact that in the eyes of School Board and other authorities controlling the education of our country the qualifications of a teacher are certificates, more certificates, as many certificates as possible—to paraphrase the sailor's wish—even though these may have been gained by mere attendance at short courses of lectures: such is our inability to distinguish between shadow and substance.

If we are to do our work at home properly and to carry on our fair share of the business of the world in competition with foreigners—not forgetting our American cousins, who promise to be by far the most serious among our competitors in the future—sounder views as to what constitutes true education must prevail. To this end we must seriously study the problem. Our School Boards must cease to wrangle perpetually over the question whether or to what extent religious dogmas shall be taught in our schools and must occasionally find time to show some slight interest in matters pertaining to sound education, thereby setting an example to their weaker brethren upon whom no elective responsibilities rest. At the outset we must order our studies primarily on utilitarian grounds, for we cannot allow our character as practical Englishmen to suffer much longer under the reproach that our system of education in schools of whatever grade, while the most unpractical possible, also shows the most complete disregard of the value of theory. Ruskin did not exaggerate when he wrote: "Modern 'Education' for the most part signifies giving people the faculty of thinking wrong on every conceivable subject of importance to them."

Be it remembered that all branches of natural science are based on facts slowly and patiently

accumulated by experiment and observation, truth having been sifted from error but gradually and oftentimes with great difficulty; and it is unreasonable to suppose that the results of the prolonged labours of innumerable inquirers can be properly brought home to and usefully assimilated by untrained workers in a few short hours. Experience shows that they are not. Those among us who have occupied the always disappointing and oftentimes very painful office of examiner all know this perfectly well and are bound to admit that our system of examinations is farcical, if not fraudulent, in the majority of cases, as a means of encouraging the acquisition of useful knowledge—by which I mean knowledge that can be used.

Knowledge alone is not power; but the knowledge how to use knowledge is. As Huxley puts it, "The great end of life is not knowledge but action."

No one would attempt to learn carpentering or cooking or dressmaking by attendance at lectures, although occasional lectures might be very useful to students of such subjects. Indeed, what kind of a carpenter would a man be who had attended lectures in which a full set of carpenter's tools had been exhibited and the use of each hurriedly defined and illustrated but whose practical knowledge had been gained by merely whittling pieces of wood with his pocket-knife?

Yet it is precisely on these lines that popular lecture courses are usually conducted; and elementary "practical" courses in chemistry, for example, have hitherto had about as much connection with the study of the subject from the practical side—*i.e.* the side of practice—as my ideal carpenter's course, in which he

spends his time in "whittling some," has to carpentry as practised by carpenters.

You must go direct to the bench and work hard there, if you wish to learn that which will be of use to you. But you must be careful neither to attempt too much nor to be in too great a hurry to learn. Again, to quote Huxley, "What men need is as much knowledge as they can assimilate and organise into a train for action; give them more and it may become injurious."

Lecturers almost invariably fail to take into consideration the rate at which mental digestion takes place; only observant teachers know how marvellously slow a process it is. University Extension lecturers are among the greatest sinners in this respect—not only the young fledglings who try their 'prentice hands at the work but also the old hands; the greatest sinners are often the popular favourites, simply because the public enjoy a performance which is full of incident. So long as lectures are regarded as a form of rational amusement this is all well and good; when it becomes a question of education, the case is altered.

I notice that it is customary in University Extension courses to preface the syllabus—itself an invention of the enemy—with a list of text-books. To those about to begin the study of science, I would, however, say in the words of *Punch*—Don't! Don't look at a text-book; avoid most of them as you would poison. Their methods are as a rule detestable and destructive of all honest effort towards development of powers of self-helpfulness; the worst offenders usually being such as are written by those who have "felt a want" in connection with some particular examination. Leave

it to those who are not called on to do work in the world to learn up facts. Let your efforts be to learn how to accomplish something.

If I were to give you a list of "text-books" it would be somewhat as follows: First I should strongly advise you to read Herbert Spencer's *Essay on Education* (Williams & Norgate), costing 1s. 11d., so that you may have clear ideas on the subject of education. It is a book that every one should study and from which much may be learnt as to why scientific habits and knowledge are of such extreme use to us in our daily life.

Then you should read the essays and lectures on scientific and sanitary subjects by the celebrated naturalist-divine, Charles Kingsley. From these you will without effort gain much instruction in scientific method—far more than from any dozen modern text-books—besides much healthy and sound advice and information of practical and moral value.

Next would come a liberal course of detective literature, beginning perhaps with Edgar Allan Poe's "Murder in the Rue Morgue" and other such stories in his *Tales of Mystery and Imagination;* then passing on to Gaboriau—in the original French, if possible—and later writers of repute in this province of literature. *Study such books*—do not merely devour them as exciting stories, until you clearly understand their method; and seek to criticise them, for they are often full of faults.

If you also read Ruskin's *Sesame and Lilies* with appreciation at this stage you will be further strengthened in pursuing your studies in the proper spirit: especially the advice he gives as to reading should be followed; and Carlyle, studied in moderation,

will here be of service in aiding you to form your character.

Then read as much as you can of the lives and doings of discoverers, explorers and inventors—of searchers after truth generally. In fact, your object should be to awaken within yourselves the spirit of the discoverer, the spirit of the explorer, the spirit of the inventor and of the investigator; to gain some inkling of their motives and methods. If you are to progress you must understand how progress has taken place. You must learn how knowledge is gained if you are to learn how to use it and you must approach its study in the proper moral attitude. Nearly all the failures of students are due to disregard of this.

There is but one technical work that I would recommend all to master at an early period in their chemical studies—that is Black's tract on *Magnesia Alba*, published in 1755, of which a reprint is now procurable from Clay, of Edinburgh, price 1s. 6d. It is probably the most perfect and philosophical statement of the work done in the course of an original inquiry ever written and must serve as a model for all time.

Now to apply this doctrine to your work. Following the anti-scientific practice which has arisen from putting new wine into old bottles—from attempting to teach science by old-fashioned and even discredited literary methods and, it cannot be denied, from laziness and the desire to do things with as little trouble to ourselves as possible, when we lecture to beginners we more often than not begin by dogmatising and then offer questionable proof of the correctness of our dogmas.

At the outset of a chemical course, for instance,

the University Extension lecturer, in good old-fashioned style, usually thinks it necessary to define chemical as distinct from physical change, instead of allowing such ideas to grow up gradually and naturally, as Topsy did: forgetting that his hearers are entire strangers to such words as "chemical" and "physical." Taking two pieces of wire, he shows that one may be made red hot without alteration while the other takes fire and burns brilliantly—as does this piece of magnesium—giving off clouds of white smoke, a mere ghostly skeleton of a brittle white earthy substance remaining. Not satisfied with demonstrating facts, he usually proceeds to fling a complete explanation at his hearers, telling them that the magnesium—which most of them have neither seen nor heard of before except perhaps in connection with Crystal Palace fireworks or the mild laxative citrate of magnesia—enters into combination with the oxygen of the air (of which again they know nothing) to form a chemical compound, oxide of magnesium. Almost immediately afterwards probably the various laws of chemical combination—definite, multiple and reciprocal—will be stated in the form of Euclidian propositions and enforced by quotations of examples all entirely strange to the listeners. In five minutes almost information is imparted which it has taken fifty years to acquire. And so throughout the course: the attitude of the lecturer, when not that of the showman, is always that of papal infallibility. The cause of true science has suffered infinite injury in this country at the hands of such teachers and of the system which makes their existence possible. They have, indeed, been false prophets!

The students who follow such courses become mere prigs—some few, it is found, can retail more or less

of the information imparted to them to an examiner —provided always that he lose no time in interrogating them—but they cannot make any effective use of it. Many, doubtless, are entertained, if not interested at the time; a few, perhaps, are attracted, but if so, they start with entirely false conceptions of the aims and methods of science and rarely recover their proper mental balance. The injury that is done when those who have been instructed in such a manner themselves seek to teach is incalculable.

As have many others, I have long protested against the system and it is fairly generally admitted to be a wrong one. But yet we do little to get "forrarder," the fact being that the deadening effect of our methods of training is such that we teachers too often go forth to our work mere machines, with the spirit of inquiry and adventure crushed out of us—slavish imitators of a long series of misguided predecessors, ever taught to follow with unquestioning obedience. And yet we English pride ourselves on our individuality, forsooth!

What is the result? Our nation is gradually being beaten in every quarter, in every field. When this occurs in athletics, *Punch* and the public not only note the fact but the former advises as to the one and only remedy against future failure—for this week, speaking as Brother Jonathan, he remarks, "Say, John, you'd better go into training again"; and the lesson will be taken to heart. But in the case of the matters which I have been discussing, there is no question of going into training again; we have not yet even begun to train properly. The nation does not know enough to understand how faulty is our system and how absolutely we court failure by adhering to the old "classical" methods which experience shows to be unfit methods of teaching

classics even. And when, half perceiving this, we seek to change, we jump straight from the frying-pan of blank ignorance into the fire of technical education, where, as a rule, we find but our old foe—the dogmatic teacher—in thin disguise and consequently are no better off.

Let me now be constructive. At the beginning of a course I would give no definitions whatever—would say nothing about the differences between changes; but having directed attention to the constant occurrence of change, would suggest that changes should be studied, in order, if possible, to discover their nature, for the study of change is the business of the chemist and no wider nor simpler definition of chemistry can be given. The method is in no way novel: it is the historical method—that used in days when examinations and text-books were not and used in principle by every explorer. For instance, I would call attention to the rusting of iron—a crime against Nature done by Nature's hands which man has constantly to deplore. Students who have already enlisted in that new force of science detectives which in the future is to render such service to our country, well read in Edgar Allan Poe and other writers of works on scientific method, will naturally in the first instance study the victim—the rust; moreover, finding themselves placed in a better position than their colleagues in the police force, inasmuch as they can have before them at the same time, if not the actually victimised iron, at least what they know to be the twin sample, as well as the rust, they will carefully contrast the unaltered with the altered substance. Having previously been well drilled in the practice of elementary physical measurements, they will require

little telling to determine among other things the relative density of each in order that they may be able to insert indisputable numerical data in place of vague statements in the report they ultimately draw up—following the practice of the ordinary police detective, who is not content to describe the victim as tall or short but takes his photograph nowadays and measures him and states the actual height in his report to headquarters. It is then ascertained that the rust is specifically much lighter than the iron, whence arises the idea that *perhaps* something is given up by the iron in rusting. How is the clue thus opened out to be followed? Surely by contrasting the weight of the rusted with that of the unrusted iron. Iron nails or tacks or borings or turnings, free from grease, are therefore weighed out in a saucer, for instance; as it is well known that iron rusts only when wet they are then wetted; after some time, when rusting has taken place, any water adherent to the rusting iron is removed by baking it. On again weighing, a considerable increase is noted. Thus it is discovered that *something* from *somewhere* becomes added to the iron during rusting. A very definite clue to the mystery is thereby gained. As water is so necessary to rusting, is not perhaps the water the active agent in rusting? How can this be tested? Surely by shutting up iron, say in a bottle, along with water. When this is done little alteration is noticed, so that water alone cannot be the cause of rusting. What other associates has iron during rusting? Surely air. A little consideration suggests that iron should be shut up along with air over water. This is done and it is observed that as the iron rusts the air disappears but never to a greater extent than about one-fifth.

In this way not only is it discovered what happens to iron in rusting but students find out that the air plays a part and an interest is awakened *in air*. They then at least easily appreciate, if they do not naturally ask the question—Is it perhaps concerned in other common changes which take place under such conditions that air may take part in them? In cases of burning, for example? Such are then studied and it is soon discovered that the air is concerned; but again only to the extent of at most one-fifth. Ultimately, on investigation, all changes which go on in air are found to be changes in which one particular constituent of the air is concerned and sooner or later students learn to know this active substance as oxygen. Working in such a manner, nothing is stated or taken for granted; step by step everything is discovered and the discoveries which are made are obviously of a most important character. Thus it is not only ascertained how iron rusts but the nature of air is disclosed and the purpose it serves made clear; and the nature of fire—that it is the outcome of the union of certain substances—is also in a measure displayed.

Let me assume that you have gone thus far and let me illustrate the manner of working out another example—the action of acids on metals. Among the common substances to which attention is directed at the outset—for, of course, the teacher does and must ever guide the work of the student, while ever on guard to avoid stating in advance the solution of the problem under consideration—will have been the acids, such as oil of vitriol, only too well known from police-court reports of vitriol-throwing, if in no other way; aquafortis, used by the jeweller in distinguishing

spurious gold; and muriatic acid or spirits of salt, used by the zinc worker, among others, in preparing his soldering fluid. After studying the corrosive action which these acids exercise on various metals, students will desire to know what happens when they dissolve metals in acids—how should they find out? The last thing to do is to tell them, the only possible greater sin being to chalk up equations having no real meaning in their eyes in explanation of what goes on—for in my opinion, at this stage, no students in our new force should have the least conception of the meaning of symbols, formulæ and equations; they should gain several good-conduct stripes for other work of more immediate importance to the force at large before being allowed to enter on such a beat.

Taking metals such as zinc and iron and perhaps magnesium and acids such as vitriolic and muriatic, they would dissolve these metals in the diluted acids, economising always by taking, in the first instance, definite small quantities of acid and metal—for "waste not, want not" should be the maxim inculcated from the very beginning in all such work, as it is of the essence of all truly scientific practice.

But in order again to be in a position to report in the most definite possible and unmistakable terms to headquarters, the young detectives should be led to ascertain—than which nothing is easier—exactly how much gas is given off in each case both by definite quantities of each metal and an excess of acid and definite quantities of acid and an excess of metal. They would thus discover that the amount of gas varied with the metal but not with the acid; and other interesting quantitative relationships would also be

disclosed, throwing light on the origin of the gas and the nature of the changes.

Proceeding next to examine the gas given off in each case, having collected sufficient, they would test it. How? How had gases been previously tested; what gases had been examined? Only those from air and of these it was known that only one allowed ordinary combustibles to burn in it. Testing the gas from each metal and either acid in this way, in each case it is found that it burns. The gas therefore is evidently different from both constituents of air. "What more can be done with it?" asks the inspector. To which the answer should come, "Surely, sir, as all burning things we have studied have burnt at the expense of the oxygen in air, this gas probably does so likewise; and if so, it may be expected to give some product. We ought to find out how it burns and what is formed from it." "Good! I leave you to set to work and follow out this clue. No better suggestion could be made," says the inspector. They soon find that the new gas will not burn in azote—the inactive part of air—but will readily enough in oxygen. On arranging an experiment to see what happens when it burns in air, in which the gas is burnt from a jet placed inside a clean bell jar full of air standing in a dish containing water, it is noticed that, as the gas burns, the water gradually rises—proving that the air is used up, as was to be expected. At the same time the cool upper surface of the jar becomes "bedewed." "Hallo!" remark the young investigators, "evidently there is a liquid product formed. We must get more of this and see what it is." Some of them may have at some time noticed that when a clean kettle full of cold water is first put

over a gas flame, liquid condenses on its surface and may suggest that by burning the gas they are studying just under a flask kept full of cold water, they will be able to collect enough of the liquid for examination. Having fitted up an apparatus which enables them to constantly generate the gas, they burn the gas and at the end perhaps of half an hour have collected sufficient liquid for examination. It looks like water. Is it water? How can this be found out? Surely by comparing it with water; but how? Well, what do we know of water? We know that it freezes in winter and boils when made hot enough; that the ice melts at a particular temperature and that the water boils at a particular temperature. Some water is therefore frozen around the bulb of a thermometer affixed by means of a loose cork near to the bottom and in the axis of a small test tube, the freezing being done by means of the penny iceman's mixture of ice and salt; when the water is frozen, the tube is detached by slightly warming it externally, leaving a cylinder of ice attached to the thermometer. The temperature at which the ice melts is then noted. Then, taking the liquid to be compared with water, this is in a similar manner frozen around the thermometer bulb and the ice is then allowed to melt, taking care to collect the liquid from it in a test tube held under it: the melting-point agrees with that found for water. Next, a little cotton-wool is wrapped around the thermometer bulb and the thermometer is held in the axis of a test tube in which a small quantity of water is briskly boiled. A similar experiment is subsequently made with the liquid from the gas. The two boiling-points agree. There can be no doubt, then, that water is produced

when the inflammable gas burns and as the gas gives rise to water when burnt in oxygen that water in some way contains these two gases. The gas may in future,—if we are prepared to talk Greek as Englishmen very often are—be termed hydrogen, which means water producer.

Just consider what an important discovery is thus made and how much is learnt in making it. But who could imagine that the study of what happens when the zinc worker dissolves some spelter in spirit of salt would have led to the establishment of so remarkable a fact as that water is composed of two gases—hydrogen and oxygen. It is just in this way, however, that important discoveries are almost always made.

I trust the examples quoted will suffice to make my meaning clear—that you will see that instruction given on such lines must have the effect of raising the intelligence of the student and developing habits of self-helpfulness. That students so taught will not only gain knowledge of facts but also of method—of scientific method—which is of far more importance. That they will learn to work with a purpose and to devise experiments calculated to afford definite information as to certain clearly defined issues; to work cautiously and exactly; to observe carefully as well as to make use of their observations; and to be logical and guarded in their judgments.

After such an introduction, lectures may be sometimes attended and text-books occasionally consulted with safety and profit—but always after the attempt has been made to discover the facts in the workshop —as there will no longer be any danger that dogmatic conclusions will be accepted without inquiry.

Such a method may, of course, be adopted—and, I believe, with profit—in popular lectures even. What I have wished to point out is that you must never be satisfied with lectures alone if you wish to do more than spend your time pleasantly—that attendance at lectures alone may do you harm instead of good and may even lead you to copy the bad example of the frog in the well-known fable.

As I said at the beginning, the student of any branch of natural science must go to the bench and work hard there. Now that we have Polytechnics here, there and everywhere, no difficulty can arise in gaining access to a laboratory; and if teachers can but be kept free from the clutches of the examination demon, or even if the demon will mend his ways and become an honourable, useful, retiring member of society, there is no reason why rational courses of instruction in all subjects should not be open to the public to an extent to meet all requirements.

XX

JUVENILE RESEARCH

Dr. Armstrong, in introducing the subject of "Juvenile Research," said that the method of which he was an advocate was referred to by some who professed to follow it as a new method, although, in fact, it was very old. In proof, he quoted a passage from the preface to Priestley's Collected Works, published in 1790 (see p. 20).

On the present occasion he desired to deal with the teaching of what was commonly called Elementary Physics. This subject was included with chemistry in the scheme put forward by the Committee of the British Association which reported in 1888-1890 on the teaching of science in schools and it is now generally recognised that exercises in physical measurement must, to some extent, precede the study of chemistry. Schemes were now in the hands of teachers which were in many ways admirable guides and yet there could be little doubt that even the best of these had been drawn up far too much from a professional academic point of view, under the influence of mathematical bias—without sufficiently considering what young children really could do with advantage,

what it was most desirable that they should do and above all that such work must be carried out on heuristic lines.

There was great danger indeed that exercises in physical measurement would be worked in too mechanical a manner—at word of command—much as were the conventional examples in mathematical text-books and that children would not be led to appreciate the true value of such work; consequently the training would not be productive of the desired effect.

It was a fundamental mistake not to let children begin experimenting at an early age and not to have faith in their intelligence and reasoning powers. In any case, they must be set to work with an object—at something which they could grasp the meaning of and which was of some interest to them; and they should be guided entirely from the point of view urged so eloquently by Priestley.

At the present juncture, however, criticism was of no value unless constructive: the only way to discover how the work could be properly and best done was to solve the problem by experiment.

Dr. Armstrong proceeded to give an account of physical experiments made during the past two years by three young children, respectively about 7, 10 and 12 years old, when they began; the plan followed throughout had been to carry on the work as though it were an investigation. In reading a little book by the late Henry Drummond, *The Monkey that would not Kill*—a charming story of an irrepressible monkey whose doings led his successive masters always to seek to put an end to him—they came across the statement that the monkey was thrown into the sea,

tied to a stone which he could not lift—and that while under water he was able to lift the stone and walk to the shore, *because the stone was lighter in water than in air.* When the children asked if this could have been the case, they were advised to try for themselves. A balance being at hand and knowing how to weigh, they weighed a heavy stone in air and in water and so discovered that the statement in the story-book *was* true. It was then agreed to continue the work and that each child should write an account in copper-plate style, describing what was done.

[At the demonstration the youngest child, $9\frac{1}{4}$ years old, briefly described the monkey's doings, speaking to lantern slides, as the pictures were cast on the screen. He also weighed a stone before the audience, using a balance placed on a drawing-board supported between two tables; a pail full of water was placed below the board and the stone was hung from one pan of the balance by means of a fine wire which passed through holes in the base of the balance and the drawing-board.]

To see if other things besides stones lost weight in water, two ebony cubes and a $\frac{1}{2}$ lb. iron weight were similarly weighed; and diagrams were then drawn and coloured showing the extent to which each object lost weight. It was evident that the loss had more to do with the size than with the original weight. The cubes could be measured but the stone and weight could not: so the bulk was determined of each object by lowering it into a tilted kettle full of water and catching the water which flowed from the spout; it was then noticed that the weight of the displaced water and the loss in weight which the object suffered in water were very nearly the same. As very large

drops fell from the kettle, a more delicate apparatus was arranged by fitting to an inverted bell jar, supported in a tripod, a bent tube drawn out to a moderately fine point. Two jars of different size were used. The results were very irregular. This led to the youngest child carrying out a *long series* of experiments to ascertain why the same object did not regularly displace the same amount of water through the jet. Eventually it was established that the amount displaced was the same, provided the jet was *clean*—but only then (through the effect of grease, etc., on the surface tension of water): thus a most important lesson in the value of cleanliness was most thoroughly learnt and impressed.

In making these experiments, it was noticed that when the jar was full, water having just ceased to overflow from the jet, quite a considerable amount of water could be added before water began again to issue from the jet. The amount required in the case of each jar and when a variety of jets were used was found by running in water from a burette. [The experiment was done by the youngest boy.] The amounts were very different: but one jar was much wider than the other. This led to the comparison of the areas of the circular sections of the different jars. Eventually the area of the water surface in each jar was ascertained.

Dr. Armstrong dwelt on the fact that, being introduced in such a way, a definite object being in view, this exercise was entered on with full understanding and appreciation of its value. When children are set in the ordinary way to find the area within a circle by means of squared paper, although they do so, it may be often, with considerable interest, probably

it rarely strikes them that such an exercise has any particular application.

As the monkey was thrown into the sea, it remained to ascertain how sea-water changed the weight of things—it was certainly different from ordinary water. So at the first opportunity, on visiting the sea-side, the balance was taken and a number of pebbles were weighed in sea-water as well as in ordinary water: they not only lost in weight but to a greater extent than in ordinary water. Finally, to drive proof fully home, a canvas bag was made and into this stones were put until the youngest child could no longer lift the bag; when this was carried into the sea by the elder children, the youngest found that he could easily lift it under water. A lesson for life was thus learnt and in the course of learning it much training of value had been received.

[The second child—a girl—read out the account she had written of this part of the work.]

The question—"Why does sea-water have more effect than ordinary water in diminishing weight?" was next considered. While the boy was engaged in, as he put it, "struggling with the bell jars," the second child—a girl—undertook the examination of sea-water. As sea-water tastes salt, perhaps there is salt in it. A measured bulk was evaporated and the residue weighed; and the *density* of the water—*i.e.*, the weight in grams of 1 c.c.—was determined. Then 10 gallons of sea-water were procured from the Great Eastern Railway Company; this was boiled down in a porcelain dish, at last almost to a paste. The solid was filtered off and the remaining liquid concentrated. After washing the solid with a little cold water, it was dissolved in water and again crystallised. In

redissolving the solid it was found that a relatively small quantity of a slightly soluble substance was present (gypsum); this was collected and weighed. The first washings from the salt, when concentrated, gave crystals of another substance, Epsom salts. The final mother liquor, on evaporation, gave a substance which rapidly attracted water when left in the air. The recrystallised salt was carefully compared with common salt in a variety of ways. It was thus discovered that sea-water contained a number of different substances.

At this point the two younger children, who had been for a time working at different subjects, came together again, while the eldest pursued the course of inquiry opened up by the observations made with sea-water. His work was prefaced by a summary of a story in Andrew Lang's *Blue Fairy Book*—"Why the Sea is Salt." Knowing that the sea is fed by rivers, which in turn are fed by springs, etc., he boiled down considerable quantities of the waters locally available and actually separated from Thames water enough salt to recognise and even taste it. Having obtained a considerable quantity of solid from the water used locally for drinking and knowing that this came from wells in the chalk, he was led to compare the solid with chalk; and from this point he was subsequently led on to study chalk fully.

The younger boy and girl had meanwhile entered on a course of experiments suggested by another story —that of the *Three Giants*, in Stead's series of 1d. *Books for the Bairns*, the three giants in question representing the powers of running water, of steam and of air in motion. [The pictures in the book were shown as lantern slides and the girl gave a clear account

of their meaning.] These experiments, like the earlier ones, had largely to do with the determination of the properties of water.

Dr. Armstrong explained that throughout the work the greatest attention had been paid to the development of a good literary style — writing, spelling, composition, having all been most carefully looked after. The children were also encouraged to draw diagrams and photographs were freely used in illustration of their work.

XXI

"DOMESTIC SCIENCE"

It will be desirable, in the first place, to be clear what domestic science is or may be; probably no two of us would give the same definition. Those who are really aware of what is implied in the word *science* will need no explanation of the meaning that may be attached to the term; and to those who are not, it will be impossible to convey one usefully. It cannot well be done by talking; true understanding can only be gained from actual experience, for it is necessary to be in some measure trained scientifically—to have done scientific work—to appreciate scientific method, at all events at its full worth. The term "scientific" implies so much more than the mere possession of knowledge! it implies the power of using knowledge with *nous* or understanding; in fact, mere knowledge counts for very little, *nous* for everything. On this account I should much like to see the word science abolished, at all events, from elementary teaching and *nous* or knowingness substituted. I believe the change would be of great advantage politically; *nous* is such a simple harmless word, almost Saxon in its brevity, with no suspicion of Greek or Latin in it to the ordinary ear and it might well pass muster unnoticed.

The general public would not object to pay for *nous*; they do, quite properly, for science; in fact, for anything having a name with a classical ring about it. This is perhaps a consequence of our extreme devotion to classics; it would be wicked to suggest that the training penetrates but skin deep and that the prejudice that the word science has some fearsome, irreligious, ultramundane, hidden meaning is never tempered by the attempt to divine its true significance.

When it is understood that the object of teaching domestic science is to secure the development of *nous* or understanding in matters domestic, no objection can or will be taken to the statement that it is a subject to be studied by all girls and in which all women must be adepts in the near future, as it is the necessary precursor of successful household management. Science in the ordinary acceptation of the term—a thorough acquaintance with and appreciation of the facts and fancies pertaining to any particular branch of knowledge—is no more necessary to the average girl than to the average boy but it will always be open to the girl with innate capabilities to cultivate such knowledge when she has successfully mastered those elements of scientific method which should be within the ken of every member of the community.

Ruskin, who knew little of scientific method and despised it accordingly but who nevertheless often unwittingly displayed marvellous scientific intuition, has gracefully said of woman—"It is of no moment to her own worth of dignity that she should be acquainted with this science or that but it is of the highest importance that she should be trained in habits of accurate thought." No clearer statement of woman's requirements could possibly be wished for or made—

it is only necessary to read thought as implying and covering action. But there can be no doubt that Ruskin meant that woman should be trained in habits of accurate action, as thought without consequent action is of no avail.

It may be permitted to a man to suggest that perhaps the failure to train woman in habits of accurate thought is a cause of many of the shortcomings of *our* weaker sex; and that we should be less behind the times if those whose slaves we are made greater demands upon us and set us a brighter example—if the women of England did but see their opportunity—if they did but understand how real is the danger ahead and spur us on to arm ourselves betimes against the enemy, whose advance guard is already upon us and who clearly will grant no quarter in the future to such as are guilty of ignorance of the laws and workings of Nature.

Training in domestic knowingness must come before training in household management if the latter is to be effective. I use the expression household management advisedly in place of domestic economy. No one in this country does or can think of economy in connection with the word domestic—common experience shows the two conceptions to be altogether incompatible. If a more rational name were given to the subject it might also be taught in a more rational manner than is at present possible. Shakespeare was not often in the wrong but he certainly was in saying "What's in a name? that which we call a rose by any other name would smell as sweet." A name is everything when it involves not merely a definition but a programme.

The point of this introduction is that if you ask

me what you are to teach and how you are to teach, I would say—anything and in any way, provided it lead to the development of *nous* in connection with household affairs. I would urge you, however, not to attempt too much but to remember always that you are seeking to form habits and not to impart mere knowledge.

No one is a stronger advocate than I am of practical teaching—of teaching which has direct reference to the life work of the pupil—and I think the most unmitigated selfish twaddle is often talked of the value of learning for its own sake; no learning is of any use which cannot be made use of. But when I say life work of the pupil, I mean the whole of it—the whole occupation during waking hours. I altogether deprecate the mixing up in school of training in method with training in practice. To mix up cooking with the study of the effects of heat, as is done in some of the schemes now in use, appears to me most undesirable. The effects of heat should be studied in such a manner and with the aid of such examples that when cooking is undertaken a clear conception should be at once formed of the part the heat plays.

The necessary subjects in a course intended to give training in domestic knowingness appear to me to be—

1. *Measurement work*—Undertaken chiefly with the object of constituting the habit of measuring.

2. *The study of water*—In so far as is necessary to understand its uses.

3. *The study of the effects of heat*—Chiefly on water, involving the study of the changes in the properties of water produced by heat changes.

4. *The study of air*—More particularly in relation

to the part it plays in ordinary changes and in the combustion of fuel and food.

WEIGH! WEIGH!! WEIGH!!!

It is now customary to devote much time to exercises involving linear measurements and the measurement of areas, using squared paper. It is easy to exaggerate the importance of such work and, as I have before pointed out, there is a growing danger that the exercises will assume the stereotyped form of the conventional arithmetic book; it is good up to the point of teaching accuracy in determining dimensions and it is most useful in connection with the arithmetic and geography teaching; but it is dry stuff and of slight ulterior value in comparison with weighing—an operation in which young children take the greatest delight, although they soon tire of exercises in mere linear measurements. And they are right, as they nearly always are. To weigh, you must get up and move about; but the rule is a stick; the balance moves and shows that it is all but alive in doing its work; action promotes action. Moreover, in weighing, all the elementary rules and operations in arithmetic are visualised—including decimals—and easily learnt. Weighing also is the basis of household thrift. I therefore always contend that weighing should be so constantly resorted to as to become an absolute habit —something should be weighed almost every day. No twaddle should be taught about the principles of the balance—let academically-inclined examiners and inspectors form a class among themselves for the discussion of all such tweedledum and tweedledee matters: the balance *should be used*. Fancy the state of perfection we shall arrive at when all cooks weigh out

the ingredients of their concoctions; when the loss in weight which the joint suffers in roasting, boiling or baking is determined and consequently some thought is exercised in such operations; when the coal put on the fire or the gas burnt is weighed—at least metaphorically—and the relation between quantity used and effect produced is constantly before us—as it must be if we are ever to put a stop to the criminal waste of coal and of almost everything going on at the present time. We cannot do this by any number of book lessons or teachers' solemn warnings spoken once or twice in that indeterminate period yclept a blue moon; habits antagonistic to wastefulness must be engendered and inculcated in some practical way. I believe the balance to be our one chance. The great success which has attended German manufacturing industry in modern times is largely a consequence of the introduction of what I would call the Spirit of the Balance into the works.

But the balance must be used from the infant in arms and kindergarten stages upwards. I am moved to make this statement by "A Science Syllabus for a Secondary School," which recently came under my notice. It is true that it is for those poor things known as boys, who apparently may be called upon to suffer almost anything short of rational treatment in these days; but as I am not sure that girls are not also likely to suffer somewhat similar treatment, I am anxious to put forward a protest and appeal on their behalf while there is yet time.

The syllabus I refer to provides that, in the first year, boys of an average age of 11½ are to be inducted into Nature Study; but linear measurements are to be begun towards the end of the year. In the second,

when, as it usually does, it develops into that rank and pretentious hybrid Physiography, it becomes a shallow fraud as a means of training. Huxley never did a worse day's work that when he put forward his lectures in the form of a text-book; as lectures and when delivered by him they were doubtless admirable but as a book they are doing infinite injury to rational teaching. You cannot study Nature unless by scientific methods. You must observe, compare, measure and weigh; and to do all these requires training. Thus, the opening sentence of the syllabus I have before referred to reads: "*The school and its surroundings.* Examination of wood and stone, of soil and gravel, comparison of soil with gravel of playground." The examination can be nothing more than word painting unless measurements of some kind are made. The main difference to the boy between garden and playground would be that he got severe gravel rash and tore the knees of his trousers when he fell on the latter. Why not then face the difficulty at once and let any kind of measurement that is necessary be made? Such work would be no more difficult to a child and far more interesting than mere weather charting. To accord relative density a place along with weighing in a third year course for boys of 13½ and to qualify it with the bracketed remark "(relative density is taken as the boy has at this period reached proportion in arithmetic)" is to reduce boys to a state of prehistoric helplessness. My friend Professor Perry would say and prove that at such an age the boy should already be far advanced in the calculus. In his recent vigorous address, as President of the Electrical Engineers, he has protested, as I am now doing, against the terrible conservatism of teachers in

holding back their pupils. Why not let the boy or girl learn to weigh, as well as to measure volume, as soon as a balance can be handled; and why not familiarise them from the outset with the conception of density—the amount of stuff in a thing—rather than with that of relative density? Why wait also until the fourth year course to trot out the sacred principle of Archimedes? How can we expect to retain our maritime supremacy if we don't teach boys to understand why ships float until they are of an age at which formerly they were thought to be capable of leading cutting-out expeditions? For further information I would refer you to Captain Marryat, who might well be consulted by teachers as to what boys can do, for his stories are not entirely the product of his imagination but are based on solid fact.

To come down from the clouds, the point I wish to make is that for the purposes of an elementary course it is unnecessary and even undesirable to spend much time on the measurement and consideration of mere lengths and areas; that it is desirable to proceed almost at once to the measurement of weights and volume. Areas can, if necessary, be treated fully as part of the arithmetic and geometry course but should as far as possible be dealt with incidentally.

Begin with solids—cubes of course. Determine their linear dimensions, study the properties of the square and find the area of the cube face. Determine the volume of the cube by a displacement method. Weigh the water it displaces and let it be seen that the weight in grams is practically the same as the volume in centimetre cubes. Although I say *do* all this, I mean, of course, *don't* do it—yourselves; but make the children do it all.

Next determine the weight of the cube and from the weight and volume, infer the density—the quantity of stuff in a cubic centimetre. Then, if you will, pay Archimedes the compliment of following his example—weigh the cube in water; you will be happy ever afterwards, as you can then determine the volume of any solid, whatever its shape, and so infer *the density in grams per c.c.* (not the relative density) of the stuff of which it is made. Determine the density of ordinary coins of copper, silver and gold and if there be a child in the class born with a silver spoon in her mouth, have that spoon tested: in other words, let no opportunity slip. You may even discourage a love of mock jewellery by contrasting its density with that of gold and silver.

Examine liquids as well as solids. Have solutions made of various strengths of salt or soda and let their density be determined and let these be used in sorting eggs—good from bad. Let some girl each day bring a sample of milk and determine its density; put the results on a diagram. Sooner or later you will be in a position to determine the degree of affinity the local milk supply bears to the pump and you may even exercise a moral influence on its quality and thus gain the goodwill of all the mothers with young children.

Have cubes made of various materials or blocks of various shapes, if you will; in any case gradually create an interest in and the desire to learn something about everything that comes to hand. In this way you will really study the school and its surroundings; you will not merely talk about them in a vague and indeterminate way. And it is so easy to deal with matters which to the classical mind bear a transcendental aspect. The ball is an object loved by children; it is

just as easy to weigh a ball as any other object in water and so determine its volume. Its diameter is measured without difficulty. A section through the middle of a ball is evidently circular. The area within a circle is easily deduced by means of squared paper and the relation of circumference to diameter—the mystic π—even more easily found with the aid of a ribbon reel or a cup. It is then child's play to develop the rule for finding the area within a circle and even to pass from the square on the radius to the corresponding cube and to discover what relation the volume of the sphere bears to π and the cube on the radius. And then in view of our interest in the land surface of our globe, you may well go on to determine the surface of a sphere by stripping off the cover from a tennis ball, spreading it out and outlining it on paper and then dividing up the area into centimetre squares. All sorts of problems about the globe then become real and easily understood. But I do not consider this example belongs properly to a girl's elementary course.

If only properly introduced, all such exercises as I have referred to are easily carried out and understood. Last year I explained how I thought they might be led up to with great advantage by means of some simple story. Another year's experience has more than confirmed this view. The story of the *Three Giants* in Stead's 1d. series of *Books for the Bairns* has proved invaluable and I most strongly recommend it as a text-book in studying the properties of water; you cannot buy a cheaper one and there is not another to equal it for very young children. And the effect of using such books is reciprocal. Gradually, as the allegory is interpreted and its meaning made clear

in practice, the force of the narrative becomes more and more obvious and afterwards less effort is required to understand a story; a hidden meaning is sought for, in fact, where before none was seen.

To conclude what I have to say about measurement work, let me insist that it is not a question of teaching mensuration by practical methods but of forming the habit of measuring and weighing with all the attendant consequences; therefore exercises such as I have referred to must be repeated *over and over again* but of course in a varied form if desirable; and they must never be mere demonstrations. As far as possible, it must always be some little piece of juvenile research work that is undertaken, some little problem that is worked out. And in order to induce habits of regular systematic observation, all sorts of measurements should be kept going and discussed—thermometer and barometer may be read; squares of flannel of known size may be weighed daily and the change in moistness determined; the amount of gas burned daily may be registered. All such observations must be recorded as diagrams: quite young children may be led to appreciate these, even if they only regard them from the same point of view as they do the wonderful way in which Alice grew taller or shorter when down the rabbit's hole in Wonderland. It must not be supposed that they cannot, because the average reader of a daily paper is blind to the meaning of the diagrams given in representation of changes in the weather conditions. And as to the value of such work, we have only to consider what we should gain if housekeepers kept before them some graphic record of the consumption of articles in common use; how much waste might thereby be prevented because noticed.

Something is needed to bring home to schools generally—kindergartens included—the mental and moral value of measurement work. If Rudyard Kipling could but be persuaded to write a song with the refrain "Weigh, weigh, weigh," which could be hummed and danced to by girls during the science lessons and sung on state occasions in colleges and universities he would be doing infinite service. A writer in the *Times* a few days ago, in a very admirable letter on "Presumptuous Judgment," complains that nowhere are young people taught "what data are necessary for the formation of a sound judgment about anything" and he points out how serious are the consequences of this neglect. If people learn to weigh things, they will perhaps in time learn to weigh opinions; the experiment is worth trying in any case.

The work I have sketched out should occupy at the very least two years. No shorter period will permit of a sufficient number of exercises being worked to produce the requisite *moral* effect. Even if the course proceed no further and yet this part be done thoroughly, a most valuable foundation will have been laid.

Water, Water, everywhere!

I pass now to the second and third sections of my programme, those relating to the determination of the properties of water and of the effect of heat changes. It is necessary to take these together. Very probably much will have been done in the course of the previous work which has a bearing on this section of the programme; in fact it is only on paper that the work can be divided up into sections; but still water will have been studied, not water as an active substance. As I have already said, the study of water may well be

introduced by reference to Stead's story of the *Three Giants.* One of the giants in this is *Aquafluens*—Moving water; and another is *Vaporifer*—Steam. The idea of work in connection with *moving* and *heated* water is delightfully brought out and in a way which appeals to children.

The study of water—the most important substance in the universe, if there be any one substance which can be said to be the most important—begins as soon as water is weighed out and its density determined and when things are weighed in it. Of course, rain water will be contrasted with the water in ordinary use. As the sea plays so important a part in our history, it is desirable and possible, now that sea water is procurable in the larger inland towns, to compare it with ordinary water at as early a stage as possible. The fact that sea water is salt naturally suggests that there is salt in it, so some is boiled down and the salt compared with ordinary salt under the microscope and otherwise—as you will. Then the amount of salt is found out (by evaporating a known quantity in a beaker—the salt creeps too much in a dish) and a solution of salt is prepared of a strength corresponding to that of sea water. A saturated solution of salt may also be made and its density, strength, etc., determined—and, if you will, the relation between the density of the liquid and the amount of salt in solution: so as to drive home the value of density as a criterion of amount of dissolved matter and hence the importance of knowledge of the density of milk, for example.

You see all this is pure nature study but scientifically worked out. In the course of the experiments, the hidden and ordinarily unperceived activity of water

is discovered. And when such information is definitely graven on your pupils' minds, you can lead them to inquire, with understanding, what the sea is and why it is salt; further, if it is only salt that is washed by rain from off the land into the rivers and so into the sea; in short, if there be not other things besides salt in the sea. It is an exercise *de luxe*, perhaps, but a true analysis, valuable beyond compare for the insight it affords, to boil down, say, 25 litres of sea water; to separate the salts—six or seven are easily isolated; and to gain some slight knowledge of their remarkably different character. To those who have had such an experience the sight of the sea must call up visions other than those of mere moving water and pleasant memories; if in early youth attention were thus called to sea water, the vacuity of mind noticeable in ordinary trippers would perhaps be tempered by some slight display of interest in the wondrous fluid before their eyes.

The separation of the water from the salt by distillation is an important exercise to have undertaken as leading to a conception of pure water, after which cloud formation and rain become possible subjects to be considered in class. If time permit, it is then worth while to gain some understanding of the relation between temperature and rate of evaporation by heating water in a cylindrical glass dish during known times at known temperatures and determining the amount evaporated. Such experiments are easily made if only proper care be taken; they have a bearing on the drying of clothes and are very valuable as leading to some notice being taken of the relation between cause and effect, as to which the average housekeeper appears to be a non-sentient

being. But their chief effect must be to develop some faint glimmering of the research spirit. A cook who had learnt to work systematically and to experiment might be very valuable and such training may eventually lead to the sterile field of British cookery becoming a region of luxuriant growth.

The boiling of water must be made the subject of most serious study. How few housekeepers really know when water does boil. That it boils at a definite point on the thermometric scale, must, of course, be noticed; but don't bother about the construction of the thermometer. Teach your pupils to use it *without breaking it* and have it used as frequently as possible. Bakers in these days know at what temperature bread should be baked; does any cook know at what temperature a pie should be baked or a joint roasted? The day must come when it will be impossible that the pie resemble either a clown's face or a cinder; when cooks have some appreciation of temperature through having learnt at school to use a thermometer. The boiling point of sea or salt water will, of course, be determined and the effect of restricting the escape of steam; there is no need to introduce the complex conception of pressure, or to give any explanation of boiling point, as all cooking is done so near the sea level in this country. But it should be made clear that the value of the digester in boiling down bones for soup depends on the raising of the boiling point. It is important also, in order that boilers may not be burst, to make it clear that water expands greatly on becoming steam—there is no better way of doing this than by determining the density of steam, which need not be a difficult operation.

There are two important investigations which may

be, or rather must be, carried out during this part of the course. To drive home the truth that even to boil water costs money and that there is no need to waste fuel over it, the amount of gas burnt in raising known weights of water to the boiling point should be ascertained by means of a gas meter attached to the burner used. The difference in efficiency between a clean, nicely polished saucepan or kettle and one coated with a stony cake of bituminous matter by use over a smoky fire could sooner or later be made apparent and the importance of considering the external as well as the internal cleanliness of cooking vessels would be generally realised.

Even the long-standing debate as to whether a metal or a stoneware teapot is to be preferred might be settled by careful determination of the rate at which water cooled in them; and of course the influence of the cosy could be taken into account. At the mention of the teapot in this connection a happy vision comes before my eyes of a time when measurement work at school will have had its proper influence, and in consequence of continued balance-worship a "quantitative sense" becomes part and parcel of the female mind: then both tea and coffee will be made of uniform strength from day to day and will lose the reputation of being subject to greater variation than even the English climate.

The office of water as a cleansing agent should be made the subject of most thorough study and none is more deserving of attention. The effect that grease has in preventing a surface from being wetted is easily noticed; it is difficult to lead people to remove grease in a rational way—by thoroughly rubbing over the dirtied surface with some soft material moistened with

soda solution and then rinsing in running water. The conventional practice of putting soda into hot water in a more or less greasy tub and then immersing the greasy objects is very ineffective in comparison.

I may here interject the hope that, if this subject be taken up, something will be done to check the sinful waste of water which is everywhere countenanced. In rinsing out a vessel it is unnecessary to fill it up with water; it is far better to allow a moderate quantity to run in, then to pour this out and to repeat these operations as often as may be necessary. The hand should always be kept on the tap and as soon as the required amount of water has been let out the tap should be closed. In laboratories and kitchens both gas and water are constantly wasted through thoughtlessness and eyelessness; the waste is of less consequence than the mental attitude which permits it to go on unchecked. If the old adage of the pounds taking care of themselves were thought of in this connection, it would be greatly to our advantage. I mention this because I am anxious to impress on teachers who may engage in elementary experimental work that they will have infinite opportunity of practically inculcating moral habits, and that it is the very fact that the work presents these opportunities that makes it of such value.

It is generally recognised that hot water has superior cleansing properties; it is well to determine whether this is because it is hot or because it has been heated. That rain water is "soft" in comparison with river or well water is also generally recognised. To trace the difference to the solid matter in solution is not difficult but, if time permit, this question should be gone into very thoroughly with the aid of soap

solution. The determination of "hardness" is a most excellent exercise and one which is very easily carried out by children.

Coming back to steam—to enforce the lesson that much heat is expended in making steam and that, therefore, steam should not be needlessly wasted, the heat capacity of steam should be determined.

As yet, I have not referred to ice—at least, its density must be determined, in order that the irresistible force with which water expands on freezing may be realised. Ocular demonstration that bursting attends solidification is easily given by filling a medicine bottle with water and freezing it. Of course, the penny-ice man's freezing mixture of ice and salt will be studied in the course of these experiments and some note made of the conditions to be observed in working with it. Ice-making being part of the cook's art, such exercises are of domestic value and are highly appreciated if a practical end be given to them: children love ices.

Air, Fire and Fuel

Of the last section in my programme, air, I propose to say nothing now: it is less necessary to deal with it, as so much has been written already on the subject; and it is impossible to deliver a text-book in an hour.

The Duchess! The Duchess!

Having used the word text-book, let me point out that no text-book must ever be allowed in classes such as are under discussion. Each child should write its own text-book and be taught to regard it as a holy possession. The notes of the work must be most carefully written out, at first as a draft but eventually

XXII

THE CONSERVATION OF MATTER

WHEN you've used up all the borax and the beads no
 longer charm,
 When you've made sufficient sulphuretted stench,
Will you kindly drop a rider on the graduated arm
 Of the little Becker balance on the bench.
You have learnt a lot of symbols, long equations and
 the rest
 And of these just like a parrot you can chatter
But have you thought of trying on your own account
 to test
 The Indestructibility of Matter?

Gramme weight—drachm weight—weight of a hundred
 grains.
 (Fifty thousand boys and girls, it's all the same
 to-day.
Each of them doing his own research, each of them
 using his brains.)
 Put the weights in the balance pan and weigh—
 weigh—weigh!

Oh, argon you have read about and modestly you own
 That you think you're fully able to declare,

With an accuracy limited by paper-space alone,
The percentage composition of the air.
You have seen the rose and jessamine grow climbing 'neath the eaves
And in autumn heard their leaves fall pitter-patter;
But do you see you're proving, as you burn the faded leaves,
The Indestructibility of Matter?

Red leaf—dead leaf—leaf that is charred and hot,
Leaf of a rose or buttercup,—it's all the same to-day.
Each of them serving to prove the law.—And what's to be done with the shot?
Put it into the balance pan and weigh—weigh—weigh!

Of your knowledge of your bone and blood's components you are proud
(No doubt you have a list of them by heart).
You can tell in learned language that would mystify the crowd
How the oxyhaemoglobin plays its part.
But you've seen the grasses growing by the margin of the lake,
And you've watched the browsing herd grow slowly fatter,
Yet have you thought you're proving, when you're lunching off a steak,
The Indestructibility of Matter?

Gramme weight—drachm weight—weight of a hundred grains.
(Fifty thousand boys and girls, it's all the same to-day.

Each of them doing his own research, each of them
using his brains.)
Put the weights in the balance pan and weigh—
weigh—weigh!

We have burrowed in the coal-pits, we have quarried
out the stone,
We have forged a house of iron in the flame.
But the whirlwind and the rain-cloud they shall reap
where we have sown,
Nought shall last of that we builded but the name.
Yet although our work shall perish, though it crumble
into dust,
Which the four winds of the heavens freely scatter,
There is evidence convincing in that scattered iron rust
Of the Indestructibility of Matter.

Brown rust—town rust—rust from the country gates,
Rust from an old torpedo boat, it's all the same
to-day.
All of it serving to prove the law.—And, what's to be
done with the weights?
Put them into the balance pan and weigh—weigh—
weigh!

M. S.

XXIII

TRAINING COLLEGE COURSE OF GENERAL ELEMENTARY SCIENCE

SYLLABUS

Object Studies.—Instruction in the methods of leading children to notice and examine carefully the materials at hand, which have been collected in their district, including botanical objects, so that they may be able to describe them and distinguish their properties and characteristics in so far as these may be determined by the eye and with the aid of a simple lens, a pocket knife or file and hammer and anvil.

Measurement of Length and Area.—Instruction in the art of measuring, especially with the object of showing the utility of measurements and of developing accuracy in descriptions having reference to the position of objects, etc. This should, as far as possible, be made part of the instruction in Mathematics and Drawing. The schoolroom and its furniture, the school building and the playground should be measured and simple plans thereof drawn to scale and coloured and their areas calculated. The instruction should involve the use of the plumb bob and level and of simple methods of measuring and setting out angles and of surveying.

Weighing.—Instruction in weighing as an exercise and as a discipline but with a definite purpose in view, *e.g.*, to obtain "statistical" information about some familiar object which may be subject to variation in weight, so that the conception of average or mean weight may be developed and established.

The measurement of volume and the determination of the relation between mass and volume (*i.e.*, density) should be led up to by determination of the loss of weight in water and other fluids and the densities of common materials should be determined in various ways.

Physical Properties of Water.—Instruction in the discovery of the properties of liquid water, ice and steam. This should include the study of the carrying power of water, with some reference to ships—of its transporting and eroding power with reference to physical geography—and of its solvent power, sea-water being considered in this connection.

The study of ice should involve the determination of its density and the consideration of the consequences of the expansion of water on becoming ice in connection with the bursting of pipes in winter and the action of frost on the soil: glaciers and icebergs may be considered incidentally.

The study of steam should involve the determination of the change of volume in water when heated, the density of steam, the vapour pressure of water at various temperatures, the heat capacity of steam; and should lead up to an understanding of its use in the steam-engine. The evaporation of water under ordinary conditions should be carefully studied over a considerable period and discussed in connection with rainfall and the airing and drying of clothes.

Physical Properties of Air.—The pressure exercised by air and similar fluids, as well as the effect on air of changes in temperature, should be studied incidentally in developing the method of determining vapour pressure. The pump and barometer, the drying power of air, ventilation, winds, etc., would require consideration in this section of the course.

Chemical Studies of Earth, Fire and Air.—Chalk or limestone, regarded as a typical earth, should be very thoroughly studied and the discovery made that it consists of lime and a gas.

The burning of ordinary combustibles and of common metals and the rusting of these latter should be studied in such a manner as to lead to the discovery of the "origin," of fire and the composition of air.

Growth of Plants.—A series of observations, as far as possible quantitative, on germination and growth of plants, leading to the discovery of their manner of growth, of the importance of water and that they derive their food both from the air and the soil. Sugar, starch, fat, lean meat, white of egg and bone should be examined incidentally, so as to establish the difference between organic and inorganic materials. Simple experiments should be made with malt extract and yeast, so that the action of enzymes in digestion and of organisms in promoting fermentation and putrefaction and decay might be understood.

NOTES ON THE TEACHING OF GENERAL ELEMENTARY SCIENCE AND THE ELEMENTS OF SCIENTIFIC METHOD.

The prime object in view in teaching this subject must be to develop individuality and to inculcate the scientific attitude of mind. In the course of the work the teachers in training should become exact workers and should be led to acquire and exercise the powers of observing and of reasoning from observation, as well as the ability to set practical questions and to obtain answers to such questions by practical means: in a word, to experiment. Not merely to make experiments to order, however, but with a carefully thought out purpose, in a carefully thought out manner, deliberately and precisely, so that they may afterwards be able to make all possible use of the information gained in giving answers to the questions raised and in devising such further experiments as may be necessary to solve the problem under consideration. An art has to be acquired —not mere knowledge; but much useful knowledge is necessarily gained in the course of such work, as the problems investigated and the materials used should, whenever possible, be chosen so as to bear on common experience and on common phenomena.

The work should be done entirely from the point of view from which the subject will be taught in the school. The course should be based on and be conterminous with the school course. It will rarely be possible, under existing conditions, to proceed to a higher stage; nor will this be necessary, as ample opportunity will always be found within the school course if it be once understood that thoroughness is

the condition of fundamental importance. Exercises that may appear to be very simple and even trivial at first, will soon be found, as experience is gained, to admit of development and to deserve serious and extended study. Moreover, it is most important that students should learn to deal with a given theme in a variety of ways and to expand it; therefore, it will be desirable to encourage them to suggest alternative methods and alternative ways of putting the same question experimentally—in fact, that they should be fully practised in working riders with little or no assistance.

The course should lead the students to become acquainted with principles and methods common to several branches of science; they should learn to understand common physical phenomena and the nature of chemical change as exemplified in everyday life; but the teaching of technical details will be quite out of place, as a rule. Everything possible should be done to encourage an intelligent interest in natural objects and an intelligent appreciation of natural phenomena.

The following scheme is drawn up by way of illustration—not so much with the object of laying down a detailed programme but rather in order to show how the subject may be treated, so as to make it clear to children that they are engaged on work in direct relation with their daily life and surroundings.

Object Studies

Object Studies—not object lessons, in which the teacher does almost everything—should form the basis

of the instruction and every attempt should be made from the beginning to give these a quantitative form.

[A (steel) foot-rule should always be available, divided on one face along one edge into centimetres and millimetres, along the other into inches and tenths, the two edges of the opposite face having the inch divided in other ways.]

Collections may be made of the various materials to be had in the district or used in daily life, in building, etc. Each of these in turn should be carefully examined and its properties determined; at the same time, each should be described in writing. In carrying out such work, much may be done with the aid of a pocket knife, a file, a hammer and anvil (a common flat-iron) and a pocket lens; in fact, when teachers have once learnt to supervise such work, they will be astonished at the opportunities it affords and how interesting it may be made; but its most important side is the effect it has in leading children gradually to notice and study things systematically and to record their observations.

While such work is going on, things generally—the room and its furniture, the school building and the playground—may be measured. Plans or maps to scale should then be drawn and coloured. Opportunity would be given in the course of such work to determine areas and the need would arise of measuring angles and of setting these out. Experiments with the plumb bob and the spirit-level would be appropriate at this stage and it would be well to teach simple methods of surveying the playground, etc., preparatory to map-making.

Even in towns, children may obtain leaves of various common trees, shrubs and plants—they might

be led to make outline drawings and even blue-paper prints of these, to measure them, to describe them, to preserve them, to skeletonise them, to draw and colour pictures of them, to notice when they appear, the changes they undergo and when they disappear, etc. Each child should record all such work in a book kept for the purpose. In the country, such work might be carried much further than in town and the eyes of the children cultivated to notice what is about them. Outline maps might be made of the school district by enlarging the survey maps by means of a simple pantograph; on these might be indicated where trees, etc., and of what kind were growing. Maps might be made showing the distribution of particular trees or plants in the district and attention drawn sooner or later to the correlated differences of soil or situation. In a similar way, outline maps might be filled in to show the features of the district.

Weighing

Weighing should be resorted to at the very earliest possible moment and should be regarded as indispensable; it should be undertaken as an exercise and as discipline, even before it becomes incidental to any experimental inquiries that may be entered upon. Quite young children can be taught to weigh and to understand what they do sufficiently to record the results. From the outset the greatest care should be taken to insist that the balance is used properly and that the weights are *never touched with the fingers, etc.* As soon as possible some piece of work should be undertaken with a definite object in view, which can be continued during a considerable period almost daily;

e.g., in the country, where fowls are kept, eggs may be weighed and their volume determined; occasionally a selected egg may be boiled hard, then weighed and afterwards separated into shell, white and yolk, each of which may be weighed. Gradually information is collected, from which the average weight and composition of eggs can be deduced. Seeds, nuts, nails, etc., may be dealt with in a similar manner. If encouraged, children will themselves suggest things to do; the sympathetic teacher will have no difficulty in devising exercises which will appeal to the class. An appropriate exercise in the country would be to take samples of soil from several localities—each time digging out a block, say, 12 in. by 12 in. by 9 in. deep—and to separate these by sieving into stones and fine soil, each of which should then be weighed. The stones might be sorted into sizes and counted, and their character noted; and the fine soil might be separated into clay, sand, etc., by elutriation. Arithmetical exercises should be combined with such work, *e.g.*, the number of seeds, shot, or nails in a packet or bagful of a certain weight should be deduced from the knowledge of the average weight of the seeds or nails and the results checked by counting.

At as early a stage as possible some question should be raised the answer to which may be found by weighing; it is all-important that this should not take the form of a mere exercise but should be regarded by the children as an inquiry. Many subjects may be suggested—the choice will depend on the conditions, especially on the materials or apparatus available; but some "clue" must be forthcoming which will serve to suggest a line of action. As an illustration, Henry

Drummond's story called *The Monkey that would not Kill* (Hodder & Stoughton, London, 1898) may be taken. In this a description is given of a troublesome monkey being cast over a cliff into the sea, with a stone tied round his neck, in order to get rid of him; in some way, however, the monkey finds out that under water the stone weighs less than it did on land and that consequently he can lift it, so he picks it up and walks ashore, thus saving his life. Such a story appeals to young children and strikes their imagination; under ordinary circumstances, however, they would probably not question the incident but it is easy to lead them to consider: "Could such a thing happen?" "Does a stone weigh less in water than in air?" "May it not be well to check such a statement, if possible?" The experiment thus suggested being tried and the statement verified, a start is made and it becomes easy to extend the inquiry. "To what extent does the stone lose in weight?" "Do all stones lose weight in the same proportion?" "The loss in weight obviously has something to do with the size of the stone—how is it related to it?" "Do other things besides stones lose weight in water: if so to what extent?" These and other similar questions come almost as a matter of course and obviously can be answered by experiment. When a variety of objects are weighed in air and water, the children are led to notice that the change in weight has more to do with the size than with the weight of the object—and this renders the determination of bulk necessary. Ultimately it is discovered that the loss in weight is proportional to the volume of the object and equal to the weight of the volume of the water the object displaces. The method of determining

volume by ascertaining loss of weight in water is thus discovered. The investigation may then be extended to sea-water and other liquids. The conception of density having been arrived at in the course of such experiments, children may be led to determine the densities of the various materials at their disposal and to express these in grams per cubic centimetre or kilograms per cubic decimetre—not as mere relative densities. (The term specific gravity should be altogether avoided.) The opportunities such work affords of making diagrams and models and of setting arithmetical and geometrical exercises should be fully utilised.

Properties of Water

These cannot be too fully studied. Many ways of entering upon their consideration may be found but in order to fix children's attention and to give them a due sense of the importance of the work in which they are engaged, it will probably be found well to centre the inquiries around a story such as that of *The Three Giants* in Stead's penny series of *Books for the Bairns*. The subjects suggested for study by such an allegory are the carrying power of water, as leading up to the understanding of ships; the power of moving water to do work, as leading up to an understanding of the way in which the land is worn away; the power of water to do work when applied to the water wheel, as leading up to the conception of energy and its measurement; the power of water to do work as steam, as leading up to the conception of heat energy and its measurement and the steam-engine.

In the beginning of the story, the giant Aquafluens is represented as carrying on his shoulder a log on

which a man is seated. Children may be led to discuss the meaning of the allegory and to explain this picture—*e.g.*, to consider what size of log would have been required to carry the man, how far it would have sunk into the giant's shoulder, *i.e.*, the water, etc.—then to make experiments with blocks of different kinds of wood to determine their carrying power when floating in water, in order to obtain the data for such calculations. The blocks having been measured and weighed, the amount of water they displaced when floating and when immersed and the weight required to sink them having been determined, the data obtained should be utilised in setting a variety of exercises; eventually the construction and carrying power of ships might be taken into consideration; the use of rafts, life-belts, inflated skins and of the air-inflated quills of feathers might be discussed in connection with such experiments; in carrying them out, if the blocks were home-made, opportunity would be given for a certain amount of carpentering and for the consideration of the differences between woods of various kinds.

Wherever opportunity occurs, attention should be directed to the work done by moving water in carving out a way for itself and in transporting earthy matter and to the way in which stones are ground down and rounded by its action. The experience previously gained that things lose weight in water will lead the children to appreciate the fact that stones are rolled about under water more easily than on land and that heavy materials may be transported by water. Examples of water action occurring in the district, or which come under the children's notice, should be carefully collected and records preserved in the form of photographs, etc.; pictures obtained from a distance

will then be appreciated and materials will be obtained for the discussion of one of the most important subjects of physical geography. Point will be given to such discussions if samples are secured from a neighbouring stream in flood and the solid matter in suspension in a known bulk of water be filtered off and weighed. The character of the evidence afforded by the presence of gravel in a district will of course be patent when the origin of gravel is once understood.

The experiments on flotation in water should be extended to other liquids, especially to sea-water, wherever possible, as ships mostly go to sea.[1] These and other experiments with sea-water should, sooner or later, give rise to the question, "Why does sea-water differ from ordinary water?" The answer must not merely be given, "Because it is salt," but must be sought experimentally; and subsequently must come the query, "Why is the sea salt?" The examination of sea, river and rain water should involve the comparison of their densities and of the amount of solid matter in solution. At a later stage, it is very desirable to study sea-water somewhat fully—to evaporate a considerable quantity and to separate the salts which crystallise out. The fact that a variety of substances having very different properties can be obtained from such a source comes as a surprise and is of the greatest interest to children. No better means can be found of directing their attention to the existence of substances differing in solubility, crystalline form, taste, when heated, etc. At this stage, attention may be called to the amount of sea-water on the globe and

[1] A great opportunity is lost if sea-water cannot be studied. For certain purposes, its place may be supplied by a solution containing 3·5 per cent. of salt.

of salt therein; if desirable, the physical geography of the sea bottom and the nature of the deposits on it may be dealt with incidentally and the foundations of geology extended.

In connection with the work on sea-water, the solubility of salt in water may be studied quantitatively and the power of water *as a solvent* made clear. The densities of solutions of different strengths should be determined, in order that the relation between density and amount of solid matter in solution may be understood. The use of the hydrometer should be taught at this stage and its value in testing milk made clear. The use of solutions of salt of known density as a means of determining the density of eggs, seeds, etc., should also be taught and the value of such determinations as a means of testing quality should be emphasised.

The study of water as ice should be undertaken at the first convenient opportunity. The observation that ice floats should be suggestive as to its density: this should be carefully determined, *e.g.*, by dropping pieces of carefully-dried ice into a 500 cc. measuring cylinder containing cooled petroleum or turpentine, noting the increase in volume, then weighing to find the amount of ice used; opportunity occurs when the ice melts to check the result by noting the volume of liquid water formed. From data thus obtained, the expansion of water on becoming ice may be calculated and the consequences of the expansion may be discussed—the bursting of pipes, the breaking up of the soil by frost, the rending of rocks—and fully illustrated. Every opportunity should be taken in winter to make simple experiments with ice—for example, strong

bottles full of water may be placed out of doors during frost. Frequently a cylinder of ice will be pushed out of the neck, which may be measured and its volume ascertained and the observed expansion compared with that calculated. Such experiments live in the memory. The formation of glaciers and icebergs may, if desirable, then be considered, as well as the work they do and pictures shown in illustration; there is opportunity in many parts of the country to call attention to evidences of one form or another of glacial action. In connection with icebergs—actual pictures of which should be shown if they are to be talked about at all—calculations of the extent to which ice is immersed in ordinary and sea water when it floats should be made and diagrams drawn. In constructing a diagram to illustrate the expansion say of the side of a cubic decimetre of water on becoming ice, opportunity is given to introduce the graphic method of ascertaining cube roots at a time when the arithmetical (algebraic) method of extracting the cube root is beyond the comprehension of children.

The numbers from say 1 to 12 are cubed and a curve is drawn with the aid of the numbers thus obtained. In the case of ice, of which say 1095 cc. are formed from 1000 cc. of water, the question that arises is, "How much longer in the side will a cube of 1095 cc. be than one of 1000 cc.?" The position of 1095 on the curve being found, the number of which it is the cube is easily read off. To check the result, the number arrived at is cubed and if the product be too far removed from the number sought a better value is found by trial. In making these comparisons it is desirable to use logarithms.

The temperature of melting ice will, of course,

be another subject of study and in many cases it will be desirable to study a freezing mixture such as the penny ice man uses and to determine the influence of salt on the freezing-point. Sea-water should be frozen and the solid separated from the liquid; the two portions should be independently examined.

The study of steam may follow that of liquid water and ice. One of the first questions to arise will be, "How hot must water be to make it pass off as steam?" This will lead to the determination of its boiling-point; and taking the experiments with ice also into account opportunity will then be given to discover how the "fixed" points on a thermometer are determined. [It is unnecessary to spend time in making one.] But water passes off as steam at temperatures much below the boiling-point, as evidenced by the drying up of water at all times of the year: it is desirable that systematic observations should be made throughout the year, besides the ordinary observations of temperature, to determine the daily loss by evaporation of water from a surface of known area; this should be correlated with temperature and wind changes and the mean thickness of the film evaporated during each month should also be deduced from the observations.

Children's attention will have been directed by the story of the three giants to the conditions under which water becomes steam and in some measure to the properties of the latter. They will easily be led to appreciate the importance of determining the density of steam as a means of discovering the extent to which water expands on becoming steam. Bearing in mind the use that is made of the steam-engine and

the need that those who have to do with household work are under to know something of the expansive power of water, the experiment is one of considerable value; and it is not difficult to carry out. A weighed bulb of known capacity having been filled with steam is closed and allowed to cool; when it is again weighed the weight is found to be considerably less—why? Having been thoroughly practised in weighing in air and water, the children may be led without difficulty to understand that the weights found are not the true weights of the things weighed, because air is displaced and there is consequently some loss in weight: the difference between the bulb full of air and that from which the air is displaced by steam is, in fact, practically the difference in weight between equal volumes of air and steam. How is the weight of the steam to be found? Simply by removing the stopper from the bulb and allowing air to flow in: the weight is then that of the condensed water plus that of the bulb as originally weighed full of air, subject to a very slight correction, which it is unnecessary to introduce, owing to the presence of a little more water vapour if the air was not saturated originally. Not only may the weight of the bulb full of steam be determined in this manner, but also that of the bulb full of air—the latter being found by adding that of the water from the steam to the difference between the original weight of the bulb full of air and that of the bulb after expelling the air by steam. The experiment becomes a most important introduction to the study of gases. It may be important to take advantage of the opportunity to determine the density of ordinary coal gas and to verify by experiment the conclusion that gases act like liquids and buoy up all objects which

they surround. If desirable, the consideration of an ordinary as well as of a fire balloon may be introduced at this stage.

The pressure exercised by steam is a subject of importance to consider. This must be led up to very carefully and gradually. How is the push or pressure exerted by a gas to be measured? Does ordinary gas exert any pressure? The experiment is easily tried and the use of a water gauge made obvious. What pressure can be exerted by a person blowing? A simple gauge is fitted up for the purpose with which the blowing power of each member of a class is tested. Supposing the pressure to be measured is big, what is to be done? Probably some will say, "Use a bigger" —meaning a wider "tube": let this be tried. It is then soon discovered that it is entirely a question of height and not of width of column — and a most important hydrostatic principle is discovered. Sucking is evidently the opposite of blowing—so the measurement of the sucking-up power of the members of the class is made. This turns out to be somewhat more difficult, as a knack is involved in sucking. As increasing the width of column does not help in measuring pressures, what will? Obviously it is to be expected that a liquid will be the more effective the denser it is. The experiment thus suggested is easily made, *e.g.*, with petroleum, water and a saturated solution of salt, by means of a tube with several branches to which tubes are attached dipping into the liquids: on sucking air out from one of the branches, the liquids rise to different heights; the several columns are then measured. It is thus discovered that the denser the liquid the shorter is the column required to balance a given pressure; and the use of mercury, as being

a very dense liquid, for the purpose of measuring considerable pressures becomes appreciated. Such experiments afford an important opportunity:—"Why," it may be asked, "does sucking out air from a tube dipping into liquid cause the liquid to rise in the tube? What pushes the liquid up?" Children see without difficulty that when the air is removed from the one side the pressure of the air on the other side forces the liquid up—that the height to which the liquid rises is a measure of the difference in the two pressures—and at once appreciate the further question, "What would happen if all the air were removed from a vessel connected with a gauge dipping into a liquid and there were no pressure on the one side—how high would the liquid rise, how high a column of liquid can the air pressure support, how great is the pressure exercised by the air, say, in grams per square centimetre or pounds per square inch?" To answer this, a gauge made of narrow glass tube may be fitted up against the wall of the room, of which the lower end dips into coloured water contained in an ordinary 6-oz. medicine bottle, the upper end being connected by means of a T-piece and rubber tubing with, say, a wine-bottle. On sucking from the free branch of the T-tube, air is removed and the water rises in the gauge; if clips are placed on the rubber connections it is easy to adjust matters so that the liquid stands at a certain level in the tube; when this has been done, the tube connecting the bottle to the T-piece is closed and the bottle is removed to a pan of water. On opening the clip water enters the bottle: this is measured. Observations may be made in this way at various heights and with bottles differing in size; and corresponding experiments may be made in which air

is blown into the bottle. In this way data are obtained permitting of the determination of the relation between volume and pressure. About one quarter of the air can be removed from a bottle by sucking with the mouth; a bicycle pump can be used in removing a further quantity or in compressing air into a bottle. A saturated solution of salt may be substituted for water in the gauge, so as to impress on the attention the effect produced by substituting a denser liquid for water. The results are plotted on squared paper so as to find the law and the height of the column of water which would counterbalance the air pressure is deduced by extrapolating the curve; the result should be verified experimentally, if possible, by means of an air-pump and a sufficient length of compo-tubing to the upper end of which a glass tube is attached, also by reference to the barometer. In this way, not only may the discovery of "Boyle's law" be led up to and actually made by children, with the aid of simplest possible apparatus and without using mercury; but also the method of weighing the atmosphere; whilst the action of the pump and of the barometer become really understood. The fluctuations of the barometer may then be discussed, both by reference to observations made in the school from day to day and with the aid of the records published in some of the papers; the nature of winds may also be considered and the value of the barometer in forecasting weather.

The method of measuring gaseous pressure having been mastered thoroughly, the pressure developed on heating water may be studied. That the pressure of the air has to be overcome by the steam will be obvious after such a course of experiments and the

question will come naturally: "What will happen if the pressure be reduced?" Simple experiments are easily made to answer this question by connecting a distilling apparatus with a large bottle and the gauge previously used; air may be either sucked out until the pressure corresponds to the removal of, say, one quarter of the air, or blown in, so as to raise the pressure, whilst the distillation is carried out—the alteration in the boiling-point conditioned by alterations of pressure is then discovered. The effect of heating water without allowing the steam to escape may then be studied with the aid of a pressure guage and the working of the steam-engine boiler made clear.

The heat capacity of steam having been carefully determined, experiments may be made to ascertain the amount of gas, spirit or petroleum burnt in raising the temperature of known amounts of water to known extents—various vessels being used (glass flasks, tin, copper and iron saucepans, clean and furred or corroded kettles), so as to emphasise the importance of paying attention to the kind of vessel used in culinary operations, in order to economise fuel.

Chemical Studies of Earth, Fire and Air

When, by exercises such as have been referred to, children have learnt to make accurate measurements and to understand thoroughly the use to which such measurements can be put in solving simple problems, it will be important for them to proceed to the study of problems of a different order, involving the discovery of the composite nature of some of the common

materials of natural occurrence, so that they may be led to understand what a chemical change is.

Limestone being a typical "rock" of very general occurrence, which is to be had almost everywhere in the form of whitening, may well be the first substance selected for investigation—being chosen rather than any other stony material because something suggestive is known about it, viz., that it is converted into lime when "burnt." That the two materials, limestone and lime, are very different—that the limestone undergoes a profound change on burning—is obvious on contrasting their behaviour when wetted; and a natural question to ask will be, "What happens to the limestone?" Wherever possible the work on such a subject should be preceded by inquiry at the limekiln in the district; in no case should the opportunity be missed of witnessing building operations in which lime is used in making mortar, so that the remarkable property of lime of slaking when wetted may be noticed. With a little care, limestone may be burnt on a small scale in the kitchen fire; mortar may be made from the lime. On considering what happens to the limestone, it may be suggested that perhaps some part is burnt away and that therefore the lime obtained is not equal in weight to the limestone burnt: it is certainly a matter of common observation that when things are burnt they are, as a rule, more or less consumed; therefore the desirability, if not the need, of ascertaining whether any definite amount of lime is formed on heating limestone will soon become apparent. When the experiment is carried out and the discovery has been made that a given limestone loses in weight to a definite extent, the question will arise, "What is lost?" Evidently something which is invisible under ordinary

conditions; but the query cannot be answered offhand, so the comparative study of the two substances must be continued. As water acts in so remarkable a manner on lime, "slaking" may be studied quantitatively and the fact established that it involves an increase in the weight—a discovery of importance, as it leads the student for the first time to recognise that the production of heat and combination are in some way to be associated. The discovery may give rise to the suggestion that the lime has been reconverted into "limestone"; the need will then be brought home to the pupil of some means of characterising "limestone." Some attention will have been paid previously to water as a solvent so that the suggestion to contrast the solubility of limestone with that of lime may easily arise: in many districts, if natural illustrations of the solubility of "limestone" do not occur, attention may be directed to the presence of solid matters in solution in waters derived from limestone formations, in order that the importance of such an inquiry may be appreciated. Solvents of greater power than water, viz., acids, may also be tried. As soon as it is observed that fizzing takes place when a limestone is brought into contact with an acid, observations may be made in which both the volume of gas produced and its weight are determined: such experiments are very easily made and are highly instructive. Soon it is discovered that the weight of gas given off from a given weight of chalk is practically equal to the loss in weight which the same weight of chalk would suffer when burnt: this serves to suggest that when converted into lime by burning, chalk is deprived of the gas which is expelled from it when it is dissolved in acid and if so, lime should dissolve quietly in acid:

the correctness of the inference is put beyond question when it is discovered that such is the case.

Observations made incidentally in studying the solubility of lime and its behaviour on slaking become of importance at this stage of the inquiry: the solution obtained will probably have been filtered into an open vessel and the clear liquid in part left to itself—out of sheer carelessness; opportunity will then be given to notice that after a time a white deposit is formed. "What is this—what is it likely to be—is it perhaps lime?" are questions that will then arise. If lime, it should dissolve quietly in acid; but it is found to fizz like limestone. Again, when the lime which has been slaked and then dried—in order to determine the change in weight—is dissolved in acid, fizzing takes place, although freshly-slaked lime dissolved quietly. "What do such results indicate?—what experiment do they suggest?" will be the questions that arise. The conventional lime-water test being thus led up to, is put in operation but not in the careless unscientific way commonly recommended: so that it may be a real test, sufficient of the precipitate must be prepared to permit of its complete examination. It must be ignited and the loss of weight determined and the residue contrasted with lime; it must be dissolved in acid and the volume and weight of gas evolved determined. On the other hand, slaked lime may be exposed in the gas obtained by the action of acid on limestone and the change in weight determined. It is ultimately established that the material of which limestone chiefly consists—"limestone stuff"—is composed of "lime stuff" and a gas; and the further important discovery is made that this gas is present in the air, although only in small proportion.

As no idea of the nature of the gas can be formed at this stage, some name must be given to it which is significant of its origin—such as "chalk stuff"—or "limestone stuff" gas: to call it by its conventional name would be entirely contrary to the spirit in which the inquiry has been conducted; indeed it cannot be too carefully remembered that "you must catch your hare before you can cook it." As limestones contain very different amounts of "limestone stuff," it is important that lime prepared from several limestones should be dissolved in water and that the precipitates obtained on exposing the solutions to the air or on passing the gas from limestone and acid into them should be carefully examined; the method of separating a pure material will thus be made clear.

The nature of limestone having been discovered, attention may be paid to changes of common occurrence and to ordinary cases of burning. The rusting of iron may well be studied, in the first instance, on account of its importance. The conditions under which iron rusts should first be carefully discussed in order that some clue may be obtained which will serve as the "motive" for an experiment. Rusting is usually attributed to water, so iron may be shut up with water in a bottle; when it is discovered that it does not rust appreciably it will be clear that water alone is not the cause of rusting and the way will be prepared for an experiment in which the iron is shut up with air over water. It will then be discovered that air is concerned in the change, but not as a whole, as only a part disappears, although always the same proportion in successive experiments; the discovery is thus made that air has parts. To test whether

that which disappears is fixed by the iron, forming the earthy substance iron rust, some iron borings are weighed out, then moistened and allowed to rust; the rusted iron is subsequently weighed.

The discovery that air is concerned in the rusting of iron will serve to suggest that it may be concerned in other common changes. Ordinary cases of burning may then be investigated. When, ultimately, it is found that, as in rusting, a certain proportion—practically always the same proportion—of the air disappears, it will be placed beyond question that air consists of an active gas mixed with an inactive gas or gases; and that all the common changes in which heat is produced are cases of combination of the substance burnt with the active gas in the air: the "origin" of fire will then have been discovered. The appropriateness of the name given to the active gas will be readily grasped when the character of the products formed on burning sulphur and phosphorus has been ascertained by testing their solutions. The isolation of oxygen may be led up to by considering what substances are known in which it is present and whether one or other of these offers any peculiarities which suggest that its study is desirable. It may be pointed out that various metals are burnt on a large scale, such as copper, iron, lead and zinc and that the earthy products are all readily obtainable; that copper, iron and zinc each yields but a single product; lead, however, gives two, litharge and red lead: these, it appears, are convertible one into the other—they may therefore be selected for study. When quantitative experiments are made it is found that the one loses, whilst the other gains, in weight when heated: the way is thus paved for the dis-

covery of the method of procuring oxygen from red lead.

The products formed on burning substances other than metals will then claim attention. It is scarcely possible to heat cold water in a glass flask or kettle over a spirit or gas flame without observing that dew is deposited. "What is this—where does it come from?" may be asked. In order to answer the question, the experiment may be carried out in such a way that a considerable quantity of the liquid is obtained; as it looks like water, it is compared with water and discovered to be water. Such experiments should be quantitative, *i.e.*, the amount of combustible burnt and of water formed should be ascertained. The production of water on burning fat (candles) or vegetable or mineral oil should be made clear in a similar way. The burning of charcoal, coal and coke may then be studied: it is soon obvious that, whatever the product, it is neither solid—as in the case of metals—nor liquid, the amount of liquid formed being very small. Perhaps it is a gas.

"How is this to be tested for?" The only gases hitherto studied and for which tests are known are that from limestone and oxygen. It cannot be the latter, as it is obtained from it; but it may possibly be the former—this is present in the air—coal and wood are continually being burnt in the air. On burning charcoal or coke in a current of air and passing the products into lime-water, a copious precipitate is formed: when sufficient of this precipitate is collected and examined quantitatively, it is discovered to be chalk stuff. The composite nature of chalk-stuff gas is thus discovered; it becomes possible thereafter to speak of the gas as carbonic gas.

The discovery that one of the two substances into which chalk or limestone is resolvable is in itself a composite substance and that it is an oxide may excite comment: the question may arise whether lime is not also an oxide, since it is so like the oxides formed on burning the metals zinc and magnesium; a comparison of the behaviour of the two substances towards acids, involving the preparation of various salts, only serves to confirm the idea that lime is probably the oxide of a zinc- or magnesium-like metal. Little more can be done than point out that the inference is a correct one; that lime is, in fact, the oxide of the metal calcium. Such experiments, however, combined with what has been learnt of the oxides formed from various common metals, will make it easy to demonstrate the nature of the common minerals and to explain the manufacture of iron and other common metals.

Should it be thought necessary that the formation of water on burning spirit, etc., should be understood, the discovery of the composition of water may be led up to by studying the action of muriatic acid on the metal zinc or iron.

XXIV

SCIENCE WORKSHOPS FOR SCHOOLS AND COLLEGES

THE importance of experimental studies carried on with the object of affording training in scientific method, as a necessary part of the ordinary course in schools generally, whatever their grade, is already so widely recognised that ere long every school will certainly need its *workshops* as well as its *class-rooms*: it is therefore desirable that the general character of the requirements should be understood, in order that buildings may be properly designed to accommodate all necessary fittings and appurtenances—and more particularly to afford the necessary working space.

In preparing such a statement, it is well to look ahead and to foreshadow the policy of the future, as the whole question of school design may assume a very different aspect in years to come; indeed, the architect may play a by no means unimportant part in helping on reforms which many think to be very necessary if practical work is to take its proper place in the ordinary curriculum of every school.

I propose to illustrate my arguments largely by reference to the new buildings at Horsham for Christ's Hospital School, which have been erected from the

designs of Mr. Aston Webb and Mr. Ingress Bell to accommodate 820 boys.

In the past it has been customary to teach some branch of science—usually either chemistry or physics or both—and laboratories have been required for this purpose; in fact, the word *laboratory* has a specific connotation in connection with the teaching or practice of some branch of experimental or observational science. Unfortunately, in introducing experimental science into schools, the mistake has been made of merely transferring red-hot embers from the university or college and then proceeding to keep the fire burning on the professional lines followed in the technical school. We are being led gradually to see that this mistake must be rectified—that it is not the province of schools to teach any branch of science technically or even specifically. We desire, in fact, to get rid of formal science and to give broad training in scientific method—to subject the young scholars to the practical discipline to be derived from experimental studies; we do not wish to make specialists of them. A step is gained by substituting the word workshop for laboratory: by so doing we not only make use of a word which is familiar to English ears but gain an enlarged and more definite conception of the kind of work to be done. Every one thinks of work done in the class-room as different from that done in the workshop. It is material to my argument that in the workshop the onus is cast on the worker rather than on the director: one of the chief objects of introducing experimental studies into schools is to train boys and girls to be self-helpful.

At Christ's Hospital the four chief rooms in the Science Block are called Science Workshops and are

distinguished by the names of Cavendish, Dalton, Davy and Faraday—all classic names in the history of English science.

If the work done in the school workshops is to be of a general character, it is obvious that the fittings must be planned and arranged accordingly.

In the past, as a rule, subjects have been taught in watertight compartments; but there is a growing tendency to co-ordinate much of the teaching, especially in the junior classes. Thus, mathematics has been taught in the class-room as a desk subject, whilst elementary physical measurements which have been neither more nor less than practical mathematical exercises have been carried on in the laboratory under the science teacher. It is urged—and with force—that the teacher of mathematics must adopt practical methods and relieve the teacher of science of much that now falls to his share. Clearly, one of two courses must be adopted—either the necessary provision must be made in the mathematics class-room for the practical study of the subject or a large part of the mathematical teaching must be transferred to the science workshop. A good deal of drawing is now done incidentally in the course of the science lessons; and gradually we are also recognising that the science work has a literary side. Everything points, in fact, to a time when class-rooms such as are now provided will be of subordinate importance in our English educational system—to a time when we shall justify our contention that we are a practical people.

To summarise my recommendations, I would say that in designing science workshops the architect and his technical advisers should have three S's in mind—*Sense, Simplicity, Space.* There should be due

knowledge and understanding of the requirements to be met—mere copying should be impossible. The provision made should be of the simplest character possible—because simplicity of provision conduces to simplicity of practice; and the space should be ample—for almost anything may be done, given sufficient space, and to grant proper space is to show proper respect.

It is not my province to consider external design or general architectural effect but I will venture to urge that money spent on judicious ornamentation is always well spent in the case of a school. We give far too little heed to the influence which surroundings exercise on young people; and if we are ever to recover the sense of artistic feeling, we must do far more to make our schools attractive. The disregard of property which seems to be so characteristic of boys at the present day—which leads them to kick open doors, to wipe their feet on the railway carriage seats, etc.—is probably a consequence of the fact that at school they are not placed under conditions which would lead them to be mindful of their surroundings. It is astonishing that the example set by Thring at Uppingham has met with so few followers hitherto: "thinking in shape" such as he advocated is one of the most powerful means of stimulating the imagination and of developing æsthetic tastes; and it is so easy to carry out his idea in these days, as magnificent photographic reproductions of the masterpieces of Nature and of Art are to be had at comparatively small cost. The moral of these remarks is that neither class-room nor corridor should be without its picture rail. I would also plead for a more liberal use of colour and of line decoration in our schools.

Before describing the science workshops at Christ's Hospital, I should say that the fittings were not thought of until long after the building was designed. Of course, to secure the best result "the punishment should fit the crime"—the building should be designed to the fittings, not *vice versa.*

They differ in an important manner from the laboratories hitherto provided for schools. On reference to the plans, it will be seen that there are four main rooms in which classes are held;[1] and that to each of these are attached a number of subsidiary rooms.

No lecture room is provided; the omission has been made of set purpose, as it was desired to discourage didactic teaching. The object of introducing experimental science into schools is to give boys and girls an opportunity of learning to do things themselves; the time devoted to such work is brief enough: they cannot afford to waste any of it in listening to formal lectures. Full provision is made in each room for such didactic teaching as may be necessary by providing a demonstration bench, in front of which there is sufficient space left free for seats in two of the rooms, whilst in the others uprights are fixed, provided with small desk tops, at which the class can stand and take notes.

Moreover, no special balance room is provided; instead of such a room, a novel fitting—a balance bench—has been introduced. At first this was provided only in the two of the four workshops which were intended for juniors but it has been found so useful that a third has been ordered, which is to be placed in the Faraday workshop. The balance bench is merely a long narrow table (2 feet by 12 feet by 3

[1] Two of these are about 75 and two about 52 feet long by 30 wide.

latter are covered with lead. In days gone by, when the only science taught was analytical chemistry, there was much washing out of test tubes to be done: consequently numerous sinks were provided. To the present day, the regulations of the science branch of the Education Department specify that there should be a water-tap and sink for every two students but fortunately the rule is qualified by an "if possible."

If only to prevent the general but inexcusable habit of wasting water from growing up, this regulation should be abolished. It is the more necessary to get rid of such a regulation, as it has done much in the past—and is still doing much—towards retarding the proper teaching of science in schools, on account of the expense involved in carrying it into execution; and it has given rise to numerous disputes, sensible people seeing that such provision is quite unnecessary. Besides the intolerable waste of water, the presence of sinks on the benches involves the constant wetting of the bench near the sink. Fortunately, the class of work now advocated for schools requires the use of water but seldom, so that there is no longer any excuse for providing sinks except in special places. But I would warn architects that they must harden their hearts on this point—as they will meet with many unimaginative teachers who will hanker after what has been, whilst others will think it so convenient to have sinks here, there and everywhere if they do not object to allow scholars to move a few feet towards a convenience. There is no more reason, however, why sinks should be everywhere in a laboratory than there is to have one in every room in a dwelling-house so that all washing up may be done on the spot. I need scarcely point out that the economy involved in

localising the water supply, sinks and drains is very great. At Horsham, in the rooms on the upper floor, all sinks have been placed near to the walls; the waste is carried down to the floor below in pipes fixed in chases in the walls. On the basement floor, cross channels have been avoided as much as possible.

The conventional top hamper which is erected on the bench in most laboratories has been got rid of; in three of the rooms an arrangement has been substituted which provides both a gas service and upright supports to which the rings, etc., required to hold apparatus can be clamped. Uprights made of quarter-inch iron gas barrel have been bolted to the table top 1 foot 6 inches from the outer edge, at intervals of about 3 feet. A few inches above the top these are fitted with crosses into each of which two eighth-inch bore gas taps (Baird and Tatlock's) are screwed. At the top, these uprights are connected together by half-inch barrel. These cross-connections form a complete circuit, which in turn is connected with the gas main brought down from the ceiling. By bridging the interval at the top by pieces of board, shelves are formed on which, for example, a vessel to be used as a reservoir may be placed; or pulleys, etc., may be hung from the cross pipes, which form a gallows along the whole length of the table. If bottles are needed these can be arranged inside the uprights along the middle of the bench. If it be desired to produce a decorative effect and to protect the wood against acids, white glazed tiles having pieces of indiarubber glued to the underside by bicycle cement may be arranged within the line of uprights. What is wanted on a school bench is working space; shelves only serve to obstruct the view and to carry bottles which are rarely used.

The arrangement which I am here advocating has been carried out in a slightly different way at the Christ's Hospital Girls' School, Hertford. Four parallel benches about 20 feet long are arranged along the length of the room. That at the windows is suitable for senior work. The remaining three are so placed that girls may work facing the light, standing against the inside edge of the two outer benches, which have wooden tops and are provided with gas but not with water; the middle bench is covered with lead and there are three sinks in it and a larger sink at either end. The girls can turn from the *working bench* to the *water bench* whenever necessary, the one water bench serving for the common use of the two sets of girls. The sinks in this bench are mainly for use as pneumatic troughs: two are 1 foot 6 inches and one is 2 feet 6 inches long. I venture to think some such arrangement as this is about the simplest and most common-sense plan that can well be adopted. The tops of the working benches overlap the cupboards 6 inches, so that the girls may sit and write at them. The gas standards are fixed 6 inches from the outer edge and are tied by the overhead mains which run along the benches and across the room.

Cupboards.—Both at Horsham and Hertford, the space below the bench top is fitted with two tiers of small cupboards; inside each cupboard there is a small drawer. Each working place has four such cupboards, so that four scholars may occupy the place in succession and each have a cupboard to dispose of. In the case of school work, the amount of apparatus to be stored by the individual scholar is usually small.

Sinks and Drains.—The ordinary earthenware sinks are not only more or less fragile themselves but when

produced extending from side to side of the cupboard. The squeegee fitted to the upper bar, blocking the interval between the glass of the rising sash and the bar in front of which the sash moves up and down, is another feature of importance which has been overlooked. The use of iron plates for the roof—and in many cases for the ends—may be recommended. It is easy to construct a slot flue exit in the angle which the iron roof plate forms with the wall by fixing an iron plate against the wall inclined outwards at the angle which will give a slot of the size necessary to secure an even draught from end to end, the size of the opening being determined by trial. The opening into the flue may be at any point inside the V-shaped flue-box which is thus formed. The gas-burner should always be placed below the opening from the closet into the upcast flue.

Much remains to be learnt as to the manner in which flues should be constructed for draught hoods. It is the case of the smoky chimney over again: some hoods work well, others badly, no one knowing precisely why. The subject needs to be taken in hand experimentally and it is important that it should be studied. In any case, flues should be made wherever possible in the walls: they are always useful.

One other point of special importance may be referred to. Whatever may be the system of ventilation adopted, there should be no competition between the exits; if provision be made for the *extraction* of the air from a room by mechanical means independently of the hoods, it cannot be expected that the flues of draught hoods will work with full efficiency, if at all; the air should be allowed to escape through open windows, if not entirely through the draught hoods.

Ventilation Hoods.—One or more of these have been provided for each of the four large workshops but they are not yet finally arranged. Their position has been determined by that of the flues, which are not always in ideal situations. Had the fact been sufficiently taken into consideration that electricity is at disposal, there can be little doubt that the use of electrically driven fans would have been provided for from the outset and that the attempt would not have been made to produce a draught by means of gas. The trials made thus far have proved that it is desirable to use fans.

The conventional ventilation hood has many faults which are perpetuated time after time; of all the fittings it is the one which most needs study and improvement. The hood is rarely properly proportioned to the work for which it is to be used; and the mistake is almost invariably made of merely providing an exit opening without reference to its position or shape. The improvement, first introduced, I believe, at the Finsbury Technical College and subsequently at the Central Technical College—which is described in Robins's *Technical School and College Building* (Whittaker and Co.: London, 1887), p. 123, plate 50—appears to have passed unnoticed. It consists in giving the flue exit opening the form of a slot extending across the hood, so that an even draught may be

be any difficulty in so placing them, it is better to form a channel in the top of the bench at the back or down the middle of a double bench; this may be arranged to drain into a sink at the end of the bench, if sinks are required. Such channels are very easily provided when the bench top is covered with lead. All pipes, whether for gas or water, should be of iron. They should be fixed on the face of the walls and above the bench top. It is all-important not to fix such fittings within the cupboards. Sinks such as I have described have been made to my entire satisfaction by the Bennet Furnishing Company.

produced extending from side to side of the cupboard. The squeegee fitted to the upper bar, blocking the interval between the glass of the rising sash and the bar in front of which the sash moves up and down, is another feature of importance which has been overlooked. The use of iron plates for the roof—and in many cases for the ends—may be recommended. It is easy to construct a slot flue exit in the angle which the iron roof plate forms with the wall by fixing an iron plate against the wall inclined outwards at the angle which will give a slot of the size necessary to secure an even draught from end to end, the size of the opening being determined by trial. The opening into the flue may be at any point inside the V-shaped flue-box which is thus formed. The gas-burner should always be placed below the opening from the closet into the upcast flue.

Much remains to be learnt as to the manner in which flues should be constructed for draught hoods. It is the case of the smoky chimney over again: some hoods work well, others badly, no *one* knowing precisely why. The subject needs to be taken in hand experimentally and it is important that it should be studied. In any case, flues should be made wherever possible in the walls: they are always useful.

One other point of special importance may be referred to. Whatever may be the system of ventilation adopted, there should be no competition between the exits; if provision be made for the *extraction* of the air from a room by mechanical means independently of the hoods, it cannot be expected that the flues of draught hoods will work with full efficiency, if at all; the air should be allowed to escape through open windows, if not entirely through the draught hoods.

Of the two systems available—that in which the draught is secured by means of a gas jet and that in which a fan is used—it may be said that each has its advantages. If the latter be adopted, it will, I think, be found advisable to localise the draught closets, much as I have advocated should be done in the case of water supply, etc., otherwise the cost of fans, more particularly the cost of working them if electricity be used, becomes excessive. I may add that to connect up a series of hoods in different parts of a room or building and to use one large fan to produce a draught through all is not really satisfactory in practice; moreover, the construction of the necessary flues introduces special difficulties and is costly.

The use of gas has the advantage that small hoods may be worked economically—so that they are to be recommended in cases in which only the occasional use of the draught hood is contemplated. But I may here utter the caution that no acid fumes should be allowed to escape into the air and that draught hoods are therefore essential wherever chemical work is to be done. I am sure it will be found in cases where electric lighting is adopted that the wiring will perish rapidly unless the precaution be taken to soak the leads in molten paraffin wax before fixing.

Special Appliances.—At Horsham, a carpenter's bench with four vices is placed in two of the rooms (Cavendish and Dalton), provision being made for storing tools and other general requisites in drawers and cupboards in a somewhat specially fitted bench provided with a zinc top. The top of this bench, it may be mentioned, is intended for use in cutting out cardboard, etc.

A small room on the extreme left of the ground

floor is fitted with two lathes (wood and metal), a drill and a circular saw, which are driven by an electromotor. As the man in charge of the workshops is a skilled mechanic, it will be possible to have a good deal of simple apparatus made on the spot by the boys —so that the manual training work will to some extent be co-ordinated with the experimental work.

A dark room for optical experiments has been partitioned off from the Faraday workshop. A dark room for photographic work is provided on the upper floor. This latter, it may be pointed out, is an all-important adjunct to the science workshops.

Arrangements for muffle and other furnaces are being made in several of the rooms.

The experience I have of school requirements, especially that gained of late in arranging the fittings at Horsham and Hertford, leads me to think that, by taking into account more carefully than has hitherto been done the character of the fittings to be introduced at the time of designing the building, it will in future be possible to improve considerably upon the arrangements which have been made in the Christ's Hospital Schools, especially in the direction of simplification.

The ideal to be aimed at, I think, is to have the whole of the room, both floor and wall space, available for the work which is to be done in it.

Wall space is invaluable for a variety of purposes—for many mechanical and physical experiments, for black-boards, for shelving, etc. I would, therefore, advocate that no benches should be fixed permanently against the walls but that all benches should be placed out in the room; also that projections into the room should be avoided and that the windows should be inserted at least six feet above the floor. There

would then be an uninterrupted wall space at disposal on all sides of the room.

Whenever possible, the steam or hot-water pipes for heating the room should be carried under gratings in channels in the floor. Radiators, etc., not only take up much space against the wall, but interfere with and damage fittings in their neighbourhood.

As to benches, I am much inclined to question the need of the elaborate provision which we have hitherto made. It is doubtful whether cupboards are required under the benches in schools; apart from the fact that there is not much to be stored by the individual scholar, cupboards tend to engender habits of untidiness —everything gets put away into them and the teacher cannot be perpetually looking after them. It is desirable to encourage the common use of apparatus and the habit of keeping things in set places and in good order. If sufficient shelving, racks, etc., be provided and cupboards for general use where necessary, there is little need for cupboards under the benches. In cases where it is necessary to put certain tools, etc., in the hands of each scholar, it would be easy to provide simple lockers against the wall or even to give each scholar a box which could be taken "out of store" at each attendance and put under the working bench during the lesson.

I should like to see steady heavy benches of the kitchen-table type made use of in many, if not in most, cases. I have spoken already of the concentration of water supply and sinks. As to gas supply, of course it is convenient to have it at all benches; and if various grades of work are to be done in a laboratory, it is almost necessary to make such provision. But I am inclined to advocate a less permanent arrangement

than that usually adopted. I should like to see an overhead system of supply with provision for establishing connection with a simple main—provided with the necessary taps—which could be taken down from pegs on the wall whenever required and fixed temporarily on the bench. To call on boys and even on girls to do a little simple gas-fitting occasionally would be to give them most useful training; some one or other would always be forthcoming with genius for such work. I have previously spoken of the importance of giving eye training in schools through surroundings—of the importance of ornament, colour, pictures, etc. Elsewhere, I have urged that an atmosphere of research should prevail in our college laboratories. From the same point of view, I would here advocate that a workshop atmosphere should pervade our school workshops; they should be arranged as and look like workshops—not like drawing-rooms. Teacher and taught should be constantly called upon to meet contingencies and difficulties—to become handy and self-helpful; and instead of being forced to stand or sit at one place during the lesson, the scholar should be encouraged to move to whatever place in the workshop is best suited for the work in hand. I am a teacher of over thirty years' standing. I have taught students of every grade. What astonishes, indeed appals me, is the absolute inability of almost all the students I meet with to help themselves. I therefore feel that our schools must take the question of hand and eye training seriously into consideration.

For such benches as I have advocated, it is unnecessary to use hard wood. But whatever wood be used in the science workshop for the tops of benches, it should invariably be thoroughly coated with paraffin

wax by ironing this in with an ordinary hot iron. Oil is useless as a protection against chemicals.

Sooner or later a wooden bench top always becomes much stained and disfigured; unless it be exceptionally well made, cracks are sure to develop. All these difficulties are overcome by the use of lead-covered benches; a long experience leads me personally to prefer these to all others. The lead should be dressed carefully over the edge of the bench; a *stout* hard-wood bead, projecting about half an inch above the bench top, should then be fixed against it, using cups and screws. A simpler plan is to clamp the lead firmly at its edge by a hard-wood bead screwed down upon the table top an inch or so in from the outer edge of the table. Before fixing the bead the surface to be hidden should be well painted, so as to make a water-tight joint. Solder should never be used in making joints in any lead work; joints should always be burnt with the blowpipe.

A few words may be said here specially with reference to girls' schools. No doubt, until teachers become more imaginative and less anxious to adopt conventional fittings, they will desire to have very formal arrangements made for experimental work. If the teacher insists on having the working benches placed in front of a demonstration table, a water bench may well be fixed flanking the benches on the one side; whilst on the other flank—assuming the door to be in the middle of the wall—the space on one side of the door may be occupied by draught hoods and that on the other by a balance bench. But provision should be made even in the case of girls for some use of tools. Most householders must have experienced feminine incapacity to understand screws, leading as

this does to the gradual disappearance of the screw nuts from domestic appliances; and they must have wished that their womenkind had some soul for such matters. The chief development must come, however, in connection with the rational study of domestic requirements: it may not be necessary nor desirable to teach our girls at school to be cooks; but they *should* learn there to understand the fundamental principles underlying cookery and all other kinds of domestic work—it should be woman's pride to do this. Men have long been victims of academic prejudices but are seeking to throw them off; unfortunately the disease is now being contracted by women and we have to deplore the all too literary bent of the curriculum in girls' schools, whether primary or secondary. By making liberal provision of space for domestic workshops, the architect may do much to turn the tide.

With regard to the treatment of wall space, as much as can be spared here and there should be properly prepared so that it may serve as a blackboard; or the special black canvas, so much used in America, should be fixed against it by battens. The old-fashioned small black-boards, like slates, are fast disappearing, with advantage to teachers and taught. Wherever there is spare space, stout battens should be fixed to the wall a few feet apart—when these are provided brackets, etc., may be fixed up at any time.

Lastly, I may point out that if it can be provided a flat roof is very valuable for many purposes—for experiments on the growth of plants, for photographic work, etc. Also that it is desirable that a number of beams be fixed firmly to the ceiling joists, from which pulleys, etc., can be suspended.

I have said nothing directly with reference to the

science workshops in colleges as distinct from those for schools. These differ considerably from school workshops in minor matters, but not in principle. I have long made up my mind that if I were called on again to design a laboratory, I should greatly simplify the fittings and follow as nearly as possible the model of the well-arranged factory.

The Board of Education has recently issued a series of rules to be observed in planning and fitting up public elementary schools, which include rules for the fitting up of a science room in ordinary schools and also for laboratories in higher grade elementary schools. The latter undoubtedly tend to favour over-provision from the point of view of this paper.[1] The inspectors who are called on to administer them have usually been brought up in the lap of luxury and have not learnt by sad experience to come down to the level of ordinary life. Large sums are being spent all over the country at the present time under such influences. It is not merely that much more money is spent than necessary: what is far worse, a false complexion is put upon the work—it becomes drawing-room practice and not workshop practice; when the scholars go out into the world, they find themselves placed under altogether strange conditions, unable to use the ordinary tools and unable either to fit into or to follow the ways of ordinary life. The outcome is most serious; some action must be taken to put the schools on a simpler footing and to bring

[1] It is implied that distinct physical and chemical laboratories are desirable. I venture to urge that the very contrary is the case—there should be no specific mention either of chemistry or of physics in an elementary school, whatever its grade, and scarcely in a secondary school. Science in its relation to common life is the subject that schools should endeavour to teach; this touches on many branches.

their work into harmony with ordinary requirements. Sir William Abney, the present head of the science branch of the Education Department, is so well aware that what is most wanted in a science workshop is space that we may hope that he will so modify the regulations as to make this the essential feature in them; and also that he will emphasise both in the regulations and in instructions to inspectors the importance of securing simplicity in the arrangements.

In conclusion, I venture to urge that some attempt should now be made to standardise the requirements both for elementary and secondary schools.[1]

[1] Plans and pictures showing the arrangements of the fittings in the Christ's Hospital Schools are given in the original paper; see also the *School World*, April 1903, for pictures of benches and fittings.

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THE END

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